Rocky Flats Environmental Technology Site: Actinide Migration Evaluation (AME)
Meeting: October 5-6, 2005
Advisory Group: Greg Choppin, David Clark, David Janecky, Leonard Lane

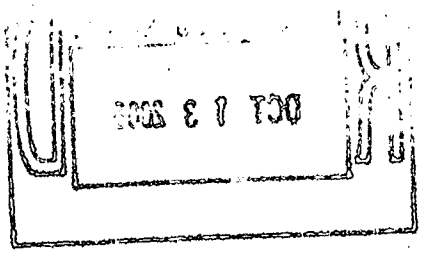
Summary and Recommendations

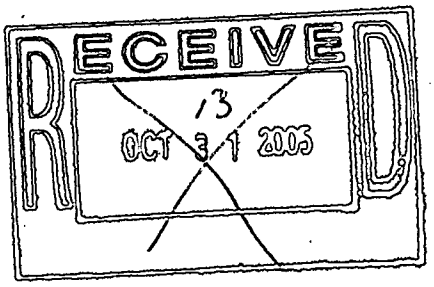
Congratulations on the hard work and thoroughness of the staff remaining to project completion to finish the remediation of RFETS. The Advisors appreciate the kind words about our contributions to the effort. Throughout our participation, we have felt strongly encouraged to provide critical advice, and that freely given comments would be carefully considered and acted upon as appropriate.

Contract completion is imminent, therefore, it continues to be very important to make the best decisions and track implementation through closure and into legacy management. Accomplishing these goals requires utilizing Site databases, modeling results, expertise, and documentation in plans and reports. The surface water monitoring projects continue to provide critical quantitative understanding of present controls, impacts, and trends. Transient Site responses are expected to last well into the Legacy Management period and will be monitored under that program.

Progress and Integration

The advisors were impressed by the Site's status and response to the monitoring results for uranium and Independent Verification and Validation (IVV). The extensive on-site knowledge of the overall water balance, drainage systems, and water flow paths allowed Kaiser-Hill personnel to rapidly identify the source of contamination, model it, and take actions. The extensive background and understanding of actinide migration provided through the Pathway Analysis afforded the scientific understanding. We were pleased with the overall integration between monitoring, modeling and treatment of the actinides. Moreover, Site closure activities and status exceeded the advisors expectations. The RFETS remediation should serve as a model for all future Superfund sites, and the entire Kaiser-Hill team is to be congratulated.





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Classification Exemption CEX-105-01

10/12/2005

ADMIN RECORD

SW-A-005202

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Results and Discussions

Surface water monitoring data

Surface water quality data for FY2005 were summarized for the remaining RFETS gauging stations. Actinide concentrations were generally less than observed in FY2004 and appear to be below the Rocky Flats Cleanup Agreement (RFCA) Action Level concentrations. The exception is an upward trend in uranium concentration (isotopic concentration data) as discussed in a subsequent section. The Advisors feel that the two pending reports (September and October, 2005) as well as future legacy management reports, should contain more complete time series of data, i.e. flow rates and amounts, contaminant concentrations, TSS and turbidity where available, and contaminant loadings. Given data in previous reports, this could be accomplished at least from 1997 through the current year. These data should be presented in graphical form and tabular data to facilitate future analyses should they become necessary. For example, Site reconfiguration effects on runoff, erosion, contaminant transport, and their loadings or yields might last as long as decades. Thus, the historical data are critical to understanding Site response to reconfiguration and legacy management operations.

Aerial and Ground Surveys

Jan Walstrom (Kaiser-Hill) discussed the results of an IVV radionuclide survey effort beyond what was agreed upon in the RFCA, to provide additional confidence and assurance. The survey effort had three components (1) a wide-area gamma scan conducted by Bechtel-Nevada and employing a state-of-the-art helicopter-mounted detector system with differential-GPS and NaI detectors, (2) a targeted ground-based confirmation scan conducted by Kaiser-Hill and employing high-purity germanium (HPGe) detectors, and (3) a targeted ground-based gamma scan conducted by ORISE and employing hand-held FIDLER instrumentation, backed up with HPGe analysis of soil samples.

Bechtel-Nevada Aerial Survey. The aerial scan used state-of-the-art differential-GPS and NaI detector systems to perform more than 44,000 individual measurements over the entire Site. This type of state-of-the-art remote sensing technology is exactly the kind of focused science that should be applied to large-scale sites with potential for radiological soil contamination. The sampling plan was well prepared and executed, and based on sound scientific principles. This massive survey effort found no significant areas of surface radiological contamination that were not already known to the Site. The AME Advisors were impressed that this aerial survey easily identified known areas of contamination such as bags of contaminated soil that were awaiting offsite shipment. This state-of-the-art aerial scan proved to be a viable technology for future large-area applications at environmental contamination concentration

levels and should be considered as a measurement technology at various stages of a site remediation from project start to project completion.

Targeted Ground-Based HPGe Survey. Kaiser-Hill personnel conducted a targeted ground-based gamma survey employing state-of-the-art high purity germanium (HPGe) detectors and following an approved Final Survey Plan. This effort performed 178 individual measurements along the boundaries of areas that had undergone remediation. The effort identified 28 locations with *in situ* HPGe readings that indicated a plutonium concentration >50 pCi/g. Subsequent alpha spectroscopy revealed that only 5 of these soil samples had actual plutonium concentrations in excess of 50 pCi/g. Those locations were remediated.

Targeted Ground-Based FIDLER Survey. Thirty six random samples were collected by ORISE and split with Kaiser-Hill for gamma spectroscopy. The random samples revealed median soil concentrations between 6 – 12 pCi/g. In addition to the random samples, ORISE personnel conducted a targeted ground-based gamma survey employing routine hand-held FIDLER instrumentation. This effort did not have a rigorous sampling plan, and focused exclusively on searching for "hot" spots. Once hot spots were identified, soil samples were collected and analyzed by both ORISE and Kaiser-Hill using gamma spectroscopy. Unfortunately, the different organizations did not use the same treatment and analysis protocol, which introduced a wide variability in the calculated values of a few individual samples. In spite of the differences in the actual values determined for a given sample, both groups measured a median plutonium soil concentration between 12 – 15 pCi/g. The fact that individual hot spots were identified that contained soil concentrations >50 pCi/g is consistent with all previous data amassed at the Site.

AME conclusion. The AME Advisors remind all interested parties that RFETS contaminated soils were extensively characterized by spatially located state-of-the-art HPGe and laboratory alpha spectroscopy analyses. Thousands of measurements were conducted on a GPS grid, and the results were utilized in a state-of-the-art geostatistical modeling approach known as "Kriging" to define the general areas for remediation. Following the remediation, over 800 confirmation samples demonstrated at the 90% confidence level that the mean concentration on the 903 Lip Area was less than 50 pCi/g (as analytical results for all 800 samples were less than 50 pCi/g) and satisfy the remediation objectives. This mean value does not preclude the potential for small areas that may exceed 50 pCi/g due to the heterogeneous distribution of "hot" particles in RFETS soils. Since plutonium in RFETS soils is in an insoluble form and associated with particles and colloids, the key to controlling plutonium/americium migration is to control wind and surface water erosional processes at the Site. Surface water and air monitoring continue to show a significant reduction of plutonium/americium after soil removal by remediation activities and the installation of erosion controls across the Site. Continued erosion control

maintenance and air/water monitoring will be the key to long-term Stewardship of the Site.

Uranium Isotopic Analyses & Evaluation

Following completion of the major remedial actions at RFETS, removal of buildings and paved surfaces, and closure of the water distribution systems, water samples from Point of Evaluation (POE) GS10 and South Walnut Creek have shown increased concentrations of uranium. GS10 samples have exceeded the RFCA standard at base flow conditions (as discussed above for monitoring data). To evaluate source terms and transport process for uranium, the Site has utilized isotopic analyses of selected samples in addition to bulk concentrations. Specifically, the presence and concentration of uranium-236 is the indicator of anthropogenic uranium contamination. To further characterize and quantify contributions of depleted and highly enriched uranium contamination to sampled waters, a method was developed to calculate mixing fractions (attached paper). The isotopic analysis shows that natural uranium has mixed with anthropogenic sources in ground and surface waters. The range of compositions observed for Rocky Flats water samples are 0-1% highly enriched uranium, 0-100% depleted uranium, and 0-100% natural uranium.

Consistent with previous documentation of uranium operations and contamination (Kaiser-Hill LLC, Pathway Analysis Summary Report and Appendices, 2002), only very small amounts of highly enriched uranium are found in a small number of water samples focused in the former Solar Ponds complex and central Industrial Area. Depleted uranium is more widely distributed and samples contain a relatively complete set of mixtures with natural uranium. However, one third of the samples are found to contain no depleted or highly enriched uranium component and three quarters of the samples are found to contain more than 90% natural uranium – substantial fractions given that the focus of these analyses was on evaluating potentially contaminated waters.

Site Tour

The AME group was taken on a Site tour to view the present state of remediation and restoration. We had a similar tour on the last visit, and the Advisors were very impressed by the extent of progress to reach closure.

The Site tour began at the entrance gate, through the old Industrial Area with stops to examine the former Building 371, 771, and 779 locations. The completion of demolition and the results of even a few months of soil restoration and plant growth had removed virtually all evidence of the former structures. The group toured along the north and south Walnut Creek drainages to examine the functional channels, monitoring stations, level of ponded water, and extent of revegetation. The group then proceeded to examine the old 903 Pad and Lip area, the SID and the Woman Creek drainage. The group was extremely

impressed with the level of attention to erosion control and the extent of revegetation across the Site. The Advisors saw no evidence of trash, construction debris, etc.

In summary, the extent of remediation and restoration of RFETS exceeded the expectations of the AME team based on the June 2005 tour. It gave the Advisors an increased level of confidence for success of the stewardship activities and the transfer of the Site to a wildlife refuge. The RFETS remediation should serve as a model for all future Superfund sites, and the entire Kaiser-Hill team is to be congratulated.

Documents Provided to Advisory Group

Agenda for meetings
RFETS Automated Surface-Water Monitoring: AME Update slides from George Squibb
Results of Aerial & Ground Gamma Surveys at Rocky Flats [to RFCAB on September 1, 2005 – first discussion of results]

Documents and Information Requested for Advisory Group

Pu & Am data from site database for all years available
2004 and 2005 water year reports from George Squibb

Participants in AME technical meetings

Name	Organization
Chris Dayton	Kaiser-Hill
Greg Choppin	Florida State
David Clark	Los Alamos
David Janecky	Los Alamos National Laboratory
Leonard Lane	Tucson, AZ.
Ian Paton	Wright Water Engineers
George Squibb	URS
David Shelton	Kaiser-Hill
Bob Nininger	Kaiser-Hill
Jan Walstrom	Kaiser-Hill
John Boylan	URS

Future Meetings

None scheduled

Attachment:
Quantitative Evaluation of Mixture Components in RFETS Uranium Isotopic Analyses – LAUR-05-7223, 26p.

LA-UR-05-7223

Approved for public release;
distribution is unlimited.

Title: Quantitative Evaluation of Mixture Components in RFETS Uranium Isotopic Analyses

Author(s): David R. Janecky

Submitted to: Kaiser-Hill LLC
RFETS Actinide Migration Evaluation

Form 836 (8/00)

Quantitative Evaluation of Mixture Components in RFETS Uranium Isotopic Analyses

Development & Verification/Validation of Calculations using an Excel Spreadsheet

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9/8/2005

Background

Uranium isotopic compositions include four isotopes (masses 234, 235, 236 and 238). Of these isotopes, three are naturally present (masses 234, 235, 238), and the isotope with mass 236 is present due to reactions that occur within nuclear reactors. The RFETS AME project has, therefore, utilized the presence and amount of ^{236}U as the indicator of uranium contamination. Uranium isotopic measurements are conventionally presented as ratios to ^{238}U, and for the purpose of evaluating isotopic compositions at RFETS, we will utilize ratios of atoms. Note that some compositions and ratios in the literature utilize the alternative units of mass rather than atoms which results in slight shifts in the resulting ratios.

Uranium processing within the nuclear and defense industrial complex has been developed to produce a range of different compositions with differing amounts of isotopic components. Primarily these compositions involve enrichment or depletion in ^{235}U. The three nominal end-member compositions for uranium present at Rocky Flats are natural, highly-enriched, and depleted (Table 1 and Figure 1). In general, highly enriched uranium was carefully physically controlled, recycled and subject to accounting. Depleted uranium was less valuable and substantial amounts were discharged to waste treatment systems, with relatively high levels discharged to the Solar Ponds. Natural uranium was not directly processed at Rocky Flats, but is present in relatively high concentrations in the geologic units that underlie the facility. For further information on uranium materials, processing, waste handling, contamination releases and environmental characterization, see the RFETS Actinide Migration Evaluation Pathway Analysis Summary Report (2002) and supporting Technical Appendices.

Requirements & Design

The purpose of this effort is to quantitatively evaluate the amount (as fractional %) of each end-member present in each field sample from RFETS that was analyzed for uranium isotopic composition. Accuracy of the calculations is targeted to be within 2% for the fraction of natural and depleted uranium.

The compositions presented in Table 1 are accepted as the end-member compositions and ratios. Analytical results in ratio format will be used to calculate the amount of each end-member. Ranges of measured isotopic ratios and plots of sample data from RFETS were used to define the range of compositions that the calculations needed to cover (Figure 2). These results showed that only a small amount of the potential range of compositions was present in the data, focused on compositions very near to the natural and depleted uranium end-members (<1% highly enriched uranium). Synthetic mixtures of the end-members can be defined by adding atomic contributions for each fraction and then calculating the resulting isotopic ratios.

A key aspect of geometric evaluation of the amounts of end-members in a three-component (triangular) mixing system is the linearity of mixing, in this case on the as a

function of isotopic ratios. Natural to depleted mixture trends were demonstrated to be linear through calculation of atom mixtures and consequent isotopic ratios (Figure 3). In contrast, the mixture of natural (or depleted) uranium with highly enriched uranium is highly non-linear (Figure 4) overall, but was found to be very close to linear, but not a direct relationship, across the range of 0-10% highly-enriched uranium in the mixture.

Because, for these RFETS samples, the amount of highly enriched uranium end-member was found to be very small (<1% from Figure 1) and less than the accuracy target for determination of natural and depleted uranium fractions, calculation of the fractional highly-enriched uranium amount can be effectively separated from calculation of the fractional amounts of natural and depleted uranium end-members. The strategy for calculation of highly enriched uranium end-member is (1) to project the sample point to the natural-enriched mix trend along a parallel to the natural-depleted trend [all points on the line of projection have equal fractional amounts of highly enriched uranium], (2) calculate the fractional distance of the projected sample point along the natural to enriched mixture line, and (3) correct the fractional distance into fractional enriched end-member using the nonlinear fit relationship from Figure 4.

The strategy adopted for calculating fraction of depleted end-member was to transform the coordinate system of the mixture triangle to place natural uranium at the origin, depleted uranium along the horizontal axis, and highly enriched uranium along the vertical axis. In detail, this strategy utilizes a shift of the compositions downward, rotation of the triangle in a counter-clockwise direction, and then skewing the triangle to the right to create a right-triangle form. While the most accurate triangular transformation would have equal intersection angles with the horizontal axis, the extremely tall, narrow, form of this triangle (Figure 1) and concentration of data near the base (Figure 2) makes the right triangle effectively equivalent and makes direct measurements simpler. The fractional amount of natural uranium is then calculated by difference. An alternative approach is to project each sample point to the natural-depleted trend line along a line parallel to the depleted-enriched trend (the equivalent approach used for determining the highly enriched end-member fraction), and this alternative was used to validate the depleted and natural uranium fractional amount results. Note that is latter approach would require a slightly more complex evaluation of limits at the extremes of natural and depleted uranium fractions if it was used as the primary method of evaluation (see discussion below).

Verification & Validation

The calculations of end-member fractions were verified and validated quantitatively by calculations utilizing isotopic ratios of synthetic trends. Synthetic trend sets of mixtures (e.g. those plotted on Figure 2) were calculated for mixing between atomic compositions of the end-member components given in Table 1. Atom ratios for each mixture were calculated, and then the fraction of each end-member was calculated using the approaches defined above. The results of these end-member fraction calculations (Table 2) are consistent for most systems with the synthetically specified fractions within the range 0-1% of highly enriched uranium and within 2% accuracy for the calculated fraction across all mixtures of depleted and natural uranium. Inaccuracy at 1% to 10% amount of highly-enriched uranium fraction is primarily due to the simple approach of determination of natural uranium by difference.

A second quantitative validation was achieved by comparing the two methods defined above for calculation of depleted uranium fraction. Because some of the sample points are just outside the bounds of the defined field for mixing between the end-member compositions, the alternative projection approach (Figure 5) gives depleted uranium fractions that are up to 10% negative at the 0% fraction limit and up to 20% lower fractions at the 100% fraction limit. This is due to uncertainties in the analytical results (which are not evaluated by these calculations) and real ranges in the compositions of depleted and highly enriched uranium "end-member" materials produced by DOE and used at RFETS (see particularly the apparent range in $^{236}U/^{238}U$ around the nominal depleted uranium end-member composition plotted in Figure 2 indicated by the sub-horizontal cluster of samples).

Lastly, the calculations of end-member fractions from isotopic ratio data for all actual samples from RFETS were qualitatively evaluated by plotting samples on axes structured following Figure 2, with sample point (bubble) sizes scaled to the fraction of an end-member (Figure 6). Inspection of these three diagrams reveals that the gradient of bubble sizes is thoroughly consistent with trends expected across the compositional ranges.

Use & Results

Six pieces of data are required for each sample to apply all functionality of the spreadsheet calculations and plots. For fraction of end-member calculations, data must be entered for the ratios $^{235}U/^{238}U$ and $^{236}U/^{238}U$. Geographic plots require entry of Northing and Easting location data for each sample. Additional data that is shown on plots is uranium concentration (ug/L) and the ratio $^{234}U/^{238}U$. Data for each sample is entered into a row in the U_Data_Summary worksheet.

Geographic plots for the data from RFETS water samples analyzed for isotopic composition are presented in Figure 7(a-h). The highest fractions of highly enriched uranium (between 0.2% and 1.0%) are found in the area of the Solar Ponds and for one sample in the center of the Industrial Area. Other samples from the Walnut Creek drainage, the Industrial Area and the Original Landfill area are found to contain 0.05% to 0.2% fraction of highly enriched uranium. Depleted uranium is more broadly distributed within the Industrial Area and at fractions between 0.5% and 100%. In addition, samples with substantial fractions (>0.5%) of depleted uranium are found across the Walnut Creek and Woman Creek drainages. Below (south) of the 903 Pad site a sample location gave consistently high depleted uranium fractions and concentrations of 270-300 ug/L. Similarly, in the area of the Original Landfill one sample location consistently gave >90% depleted uranium fraction and concentrations between 350 and 750 ug/L.

Most high concentrations of uranium in water samples correspond to areas with the highest fractions of depleted uranium. The highest concentration sample (3000 ug/L) has calculated fractions of 82% and 0.6% depleted and highly enriched uranium, respectively. Samples with concentrations between 250 and 1000 ug/L are distributed between fractions of depleted uranium of ~100% (4 samples), ~50% (4 samples) and 0% (5 samples). In these samples, highly enriched uranium fraction is approximately 0.5% in the 5 samples with ~50% depleted uranium fraction and lower than 0.13% in samples with ~100% depleted uranium fraction. One of the samples with 0% depleted

uranium fraction contained 0.03% highly enriched uranium fraction, while another is the natural uranium sample with high total concentration from the Rock Creek drainage at the northern edge of the site. Similar distributions are found at lower concentrations, with higher numbers of samples not containing depleted or highly enriched uranium.

Conclusions

A spreadsheet based computational approach has been developed and tested for determining and graphically displaying the fractional distribution of uranium end-members (natural, depleted and highly enriched) from isotopic analytical results for water samples. The approach was specifically verified and validated for the range of compositions observed for Rocky Flats (0-1% highly enriched uranium fraction, 0-100% depleted uranium fraction, and 0-100% natural uranium fraction).

Consistent with previous documentation of uranium operations and contamination (Kaiser-Hill LLC, 2002), only very small amounts of highly enriched uranium are found in a small number of water samples focused in the former Solar Ponds complex and central Industrial Area. Depleted uranium is more widely distributed and samples contain a relatively complete set of mixtures with natural uranium (Figure 5). However, one third of the samples are found to contain no depleted or highly enriched uranium component and three quarters of the samples are found to contain more than 90% natural uranium – substantial fractions given that the focus of these analyses was on evaluating potentially contaminated waters.

References

Kaiser-Hill LLC (2002) Actinide Migration Evaluation Pathway Analysis Summary Report, *Kaiser-Hill Company, US Department of Energy Rocky Flats Environmental Technology Site, Golden, CO*, 33p. (& Technical Appendices)

Table 1. Isotopic compositions and ratios for three nominal end-members of Uranium

Atom %	^{234}U	^{235}U	^{236}U	^{238}U
Natural (U)	0.0057	0.720	0.0000	99.280
Depleted (DU)		0.190	0.00359	99.807
Highly enriched (HEU)		99.123	0.503	5.374

	$^{234}U/^{238}U$	$^{235}U/^{238}U$	$^{236}U/^{238}U$
Natural (U)	0.0000574	0.007253	0.000
Depleted (DU)		0.00190	0.000036
Highly enriched (HEU)		17.513	0.09352

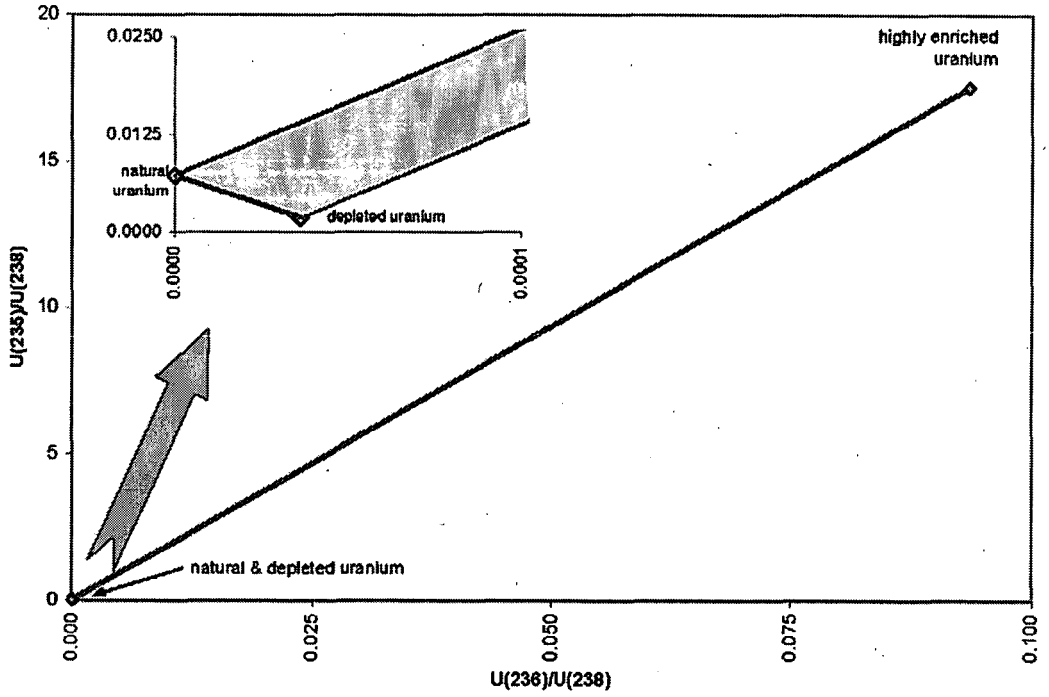

Figure 1. Triangular area of mixing (green shaded field) between natural, depleted and highly enriched uranium within the isotopic ratio plot for ^{236}U, ^{235}U relative to ^{238}U. The triangular area of mixing has a very short base between natural and depleted compositions, with nearly equivalent sides to the highly enriched composition. Samples from RFETS are found in the lower left of the mixing area, very close to natural and depleted end-member compositions (Figure 2).

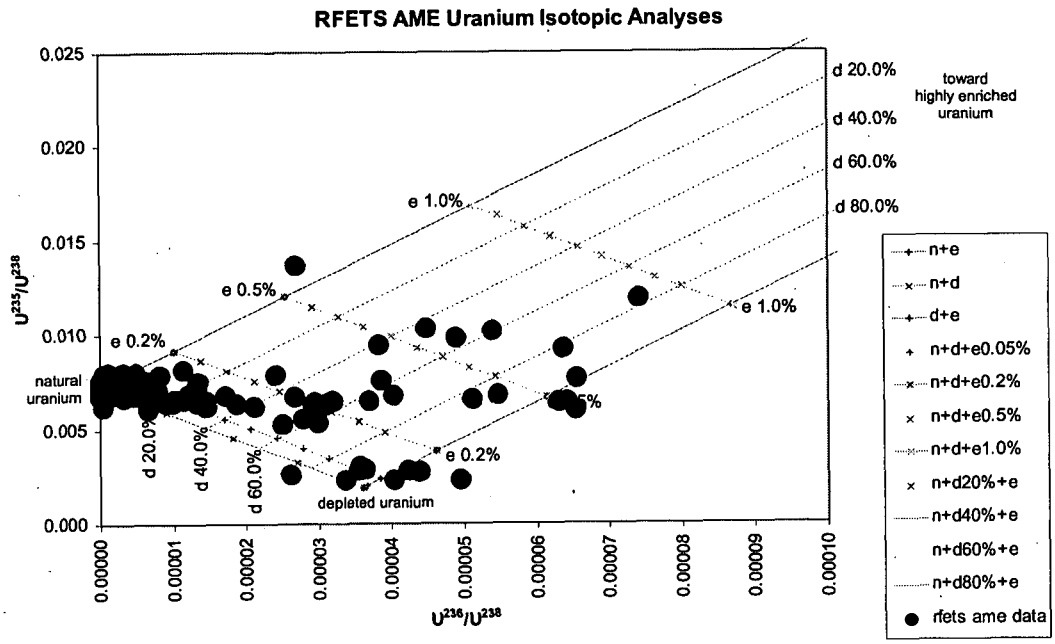

Figure 2. Sample set of uranium isotopic analyses from RFETS in ratio format. The lines contain the area of mixing between the end-member compositions (Table 1 and Figure 1), with natural uranium composition at the left apex, depleted uranium at the lower, central apex, and highly enriched uranium well to the right, upper corner, of the frame.

Calculated trends for synthetic intermediate mixtures with specified fixed amounts of highly enriched (0.05, 0.2, 0.5, and 1.0%) or depleted (20, 40, 60, and 80%) uranium are shown with intermediate lines. Comparison of the RFETS sample data with these mixing lines shows that the maximum fraction of highly enriched uranium end-member is less than 1.0%.

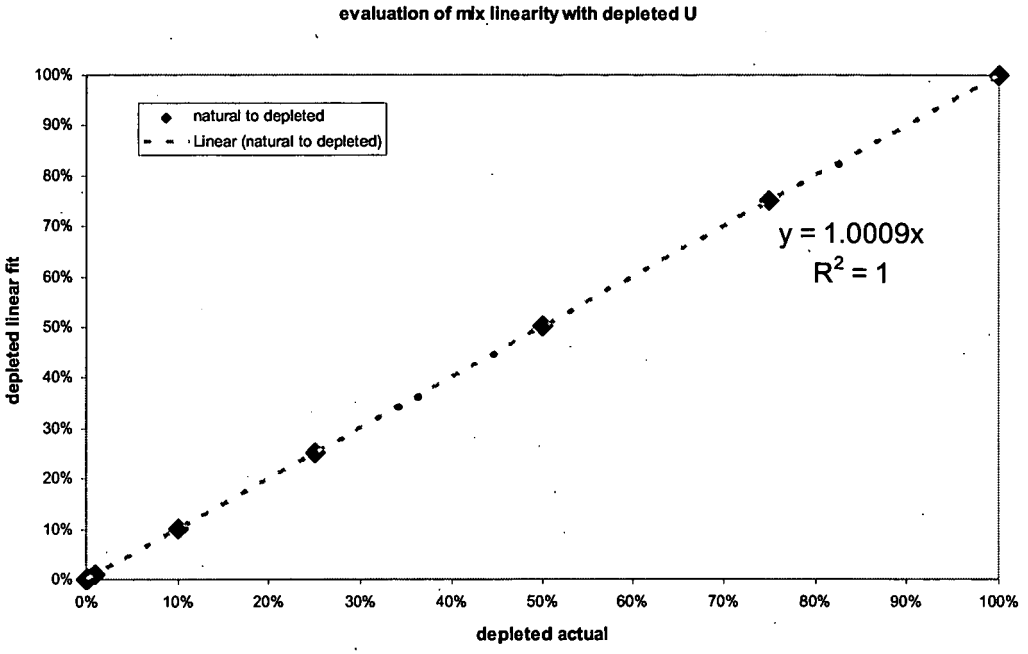

Figure 3. Evaluation of mixing trend from natural to depleted uranium compositions (Table 2, second set). The figure shows the accuracy of a linear fit across the entire mixing range from natural to depleted uranium by comparing results for specific fractional mixes (diamond symbols) with a linear fit (dashed gray line), and the calculated equation of the fit line and measure of goodness of fit (R^2). Therefore, the shifts found on atom ratio plots (e.g. Figures 1 & 2) are linear between these end-member compositions.

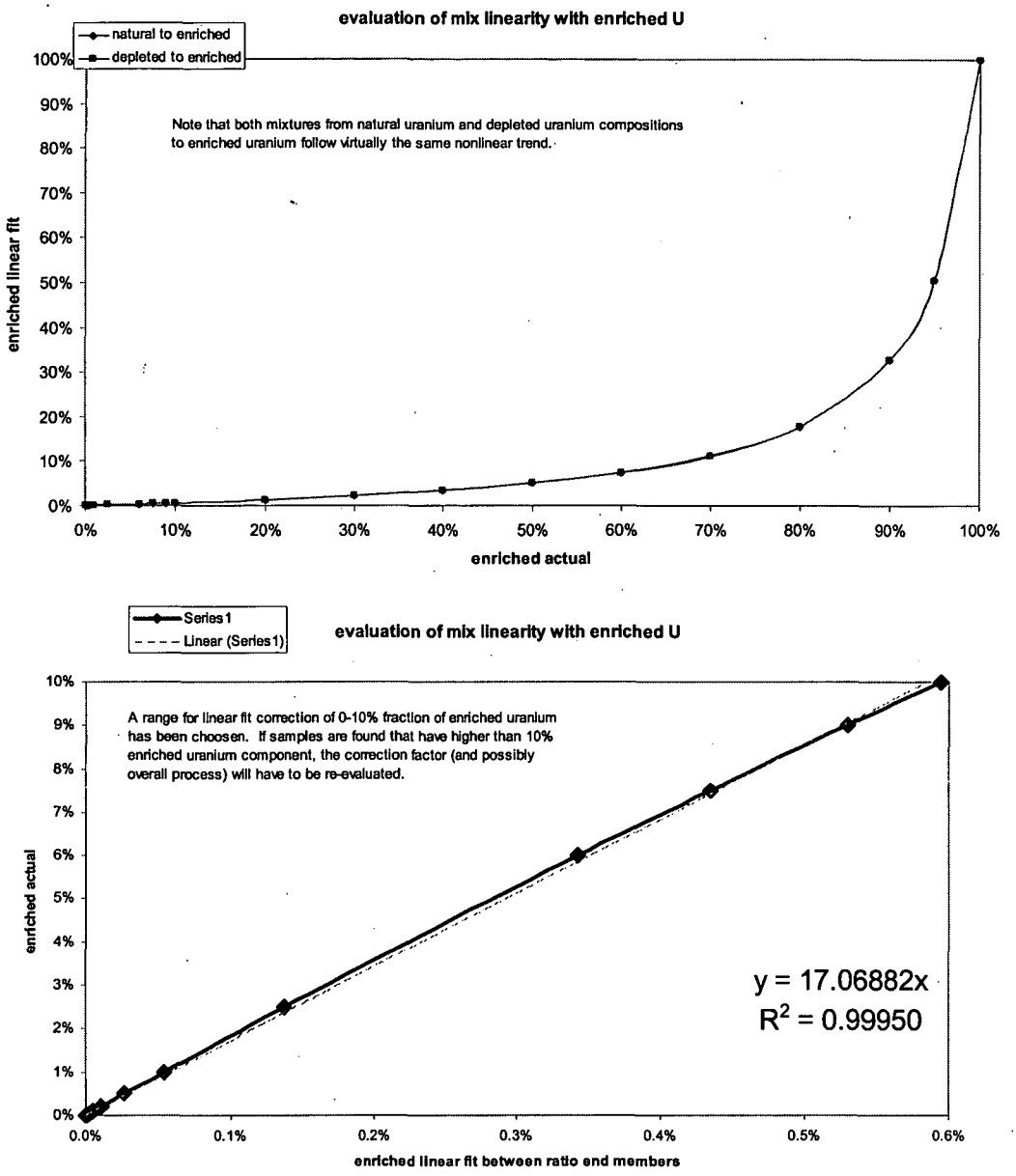

Figure 4. Evaluation of mixing trend from 100% natural (or 100% depleted) to 100% highly enriched uranium compositions. Estimated fraction of highly enriched uranium is calculated from isotopic ratio compositions, and compared on the plots to synthetic mix compositions. Because the compositions are mixtures of multiple isotopes, the shifts found on the atom ratio plot (e.g. Figure 1) are nonlinear. The upper plot demonstrates that mixing from natural and depleted end-members are very similar. The lower figure shows the accuracy of a linear fit between 0% and 10% highly enriched uranium is very good, with a factor of 17.07.

Table 2. Evaluation calculations for fractions of end-members for synthetic mixture compositions.

	synthetic ratios		% fractions calculated		
	u236/u238	u235/u238	depleted	enriched	natural
QC checks					
Set 1: natural plus					
e0.00%	0.00000000	0.007253			
e0.01%	0.00000051	0.007348	0.00%	0.0092%	99.9908%
e0.05%	0.00000253	0.007727	0.00%	0.0462%	99.9538%
e0.10%	0.00000507	0.008202	0.00%	0.0923%	99.9077%
e0.20%	0.00001014	0.009152	0.00%	0.1849%	99.8151%
e0.50%	0.00002543	0.012014	0.00%	0.4635%	99.5365%
e6.00%	0.00032204	0.067534	0.00%	5.8688%	94.1312%
e7.50%	0.00040869	0.083755	0.00%	7.4480%	92.5520%
e9.00%	0.00049804	0.100479	0.00%	9.0763%	90.9237%
e10.00%	0.00055915	0.111919	0.00%	10.1901%	89.8099%
e20.00%	0.00124876	0.241005	0.00%	22.7576%	77.2424%
e30.00%	0.00212051	0.404185	0.00%	38.6444%	61.3556%
e40.00%	0.00325754	0.617022	0.00%	59.3658%	40.6342%
e50.00%	0.00480266	0.906250	0.00%	87.5243%	12.4757%
e60.00%	0.00702364	1.321989	0.00%	127.9998%	-27.9998%
e70.00%	0.01048806	1.970484	0.00%	191.1358%	-91.1358%
e80.00%	0.01664609	3.123189	0.00%	303.3605%	-203.3605%
e90.00%	0.03063714	5.742133	0.00%	558.3350%	-458.3350%
e100.00%	0.09352000	17.513000	0.00%	1704.3200%	-1604.3200%
Set 2: natural plus					
d0.00%	0.00000000	0.007253			
d0.01%	0.00000000	0.007252	0.01%	0.0000%	99.9899%
d0.05%	0.00000002	0.007250	0.05%	0.0000%	99.9497%
d0.10%	0.00000004	0.007248	0.10%	0.0000%	99.8995%
d0.20%	0.00000007	0.007242	0.20%	0.0000%	99.7989%
d1.00%	0.00000036	0.007199	1.01%	0.0000%	98.9947%
d10.00%	0.00000362	0.006715	10.05%	0.0000%	89.9523%
d25.00%	0.00000904	0.005909	25.10%	0.0000%	74.9006%
d50.00%	0.00001805	0.004569	50.13%	0.0000%	49.8677%
d75.00%	0.00002704	0.003233	75.10%	0.0000%	24.9009%
d100.00%	0.00003600	0.001900	100.00%	0.0000%	0.0000%

Notes:

Orange highlighted cells indicate calculations beyond the range of the linear fit developed in Figure 4.

Pink highlighted cells indicate calculation results that are negative and beyond the specified accuracy target of 2%.

Yellow highlighted cells indicate calculation results for fraction natural uranium that are less than or equal to 0%, but within the 2% accuracy target specified.

Green highlighted cells indicate calculation results where the fraction of natural and depleted uranium is within the specified accuracy target of 2% and the fraction of highly-enriched uranium within the linear fit range.

Table 2 (continued). Evaluation calculations for fractions of end-members for synthetic mixture compositions.

	synthetic ratios		% fractions calculated		
	u236/u238	u235/u238	depleted	enriched	natural
Set 3: depleted plus					
e0.00%	0.00003600	0.001900	100.00%	0.0000%	0.0000%
e0.010%	0.00003650	0.001994	100.00%	0.0092%	-0.0086%
e0.050%	0.00003852	0.002372	100.00%	0.0459%	-0.0432%
e0.100%	0.00004104	0.002844	99.99%	0.0919%	-0.0865%
e0.200%	0.00004609	0.003789	99.99%	0.1839%	-0.1731%
e0.500%	0.00006129	0.006637	99.97%	0.4611%	-0.4340%
e1.00%	0.00008682	0.011420	99.95%	0.9265%	-0.8722%
e2.50%	0.00016490	0.026045	99.86%	2.3500%	-2.2121%
e5.000%	0.00030020	0.051389	99.72%	4.8166%	-4.5340%
e6.000%	0.00035622	0.061882	99.66%	5.8379%	-5.4954%
e7.500%	0.00044239	0.078023	99.57%	7.4089%	-6.9742%
e9.000%	0.00053123	0.094665	99.47%	9.0286%	-8.4988%
e10.000%	0.00059201	0.106049	99.41%	10.1366%	-9.5419%
e20.000%	0.00127778	0.234506	98.67%	22.6391%	-21.3107%
e30.000%	0.00214476	0.396905	97.74%	38.4451%	-36.1893%
e40.000%	0.00327569	0.608747	96.53%	59.0632%	-55.5977%
e50.000%	0.00481276	0.896667	94.89%	87.0859%	-81.9762%
e60.000%	0.00702265	1.310615	92.53%	127.3746%	-119.9009%
e70.000%	0.01047086	1.956522	88.84%	190.2395%	-179.0773%
e80.000%	0.01660342	3.105251	82.28%	302.0429%	-284.3207%
e90.000%	0.03055246	5.718137	67.36%	556.3498%	-523.7063%
e100.000%	0.09352000	17.513000	0.00%	1704.3200%	-1604.3200%
Set 4: natural plus 20% depleted plus					
e0.000%	0.00000723	0.006178	20.08%	0.0000%	79.9152%
e0.010%	0.00000774	0.006272	20.09%	0.0092%	79.9041%
e0.05%	0.00000976	0.006651	20.09%	0.0461%	79.8596%
e0.100%	0.00001230	0.007124	20.10%	0.0923%	79.8039%
e0.200%	0.00001738	0.008073	20.12%	0.1847%	79.6925%
e0.500%	0.00003267	0.010929	20.18%	0.4630%	79.3568%
e6.000%	0.00032934	0.066326	21.29%	5.8622%	72.8459%
e7.500%	0.00041601	0.082510	21.62%	7.4395%	70.9438%
e9.000%	0.00050536	0.099196	21.95%	9.0657%	68.9827%
e10.000%	0.00056648	0.110609	22.18%	10.1781%	67.6413%

Notes:

Orange highlighted cells indicate calculations beyond the range of the linear fit developed in Figure 4.

Pink highlighted cells indicate calculation results that are negative and beyond the specified accuracy target of 2%.

Yellow highlighted cells indicate calculation results for fraction natural uranium that are less than or equal to 0%, but within the 2% accuracy target specified.

Green highlighted cells indicate calculation results where the fraction of natural and depleted uranium is within the specified accuracy target of 2% and the fraction of highly-enriched uranium within the linear fit range.

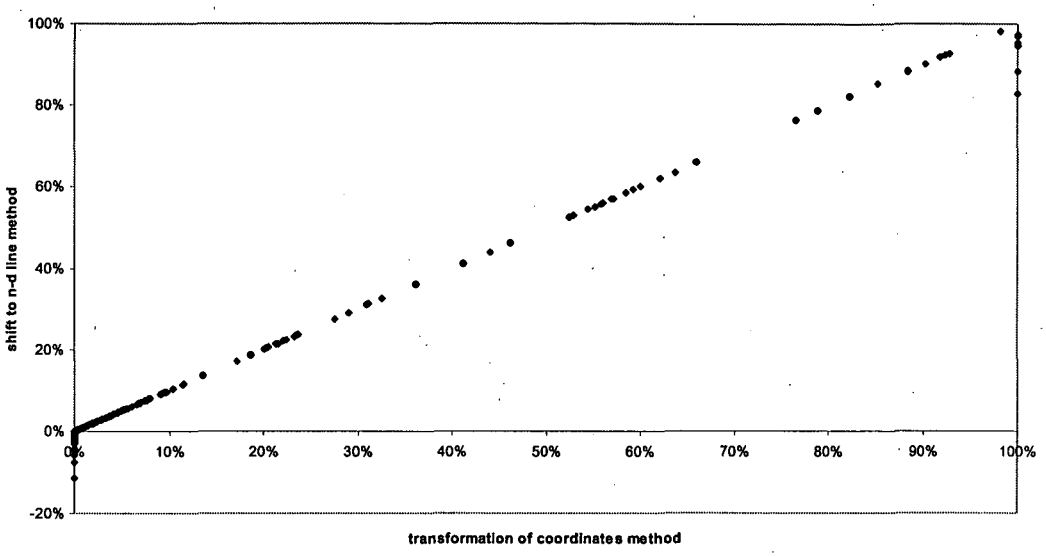

Figure 5. Comparison in RFETS sample data for fraction calculated of depleted uranium end-member in mixtures with natural uranium end-member for the two independent approaches to geometric transformation as described in text. The two methods give effectively identical results, except for samples at extremes of the mix area, where the transformation calculations have limits of 0-100% fractions enforced and the shift to natural-depleted mix line calculations do not have such real, physical limits enforced.

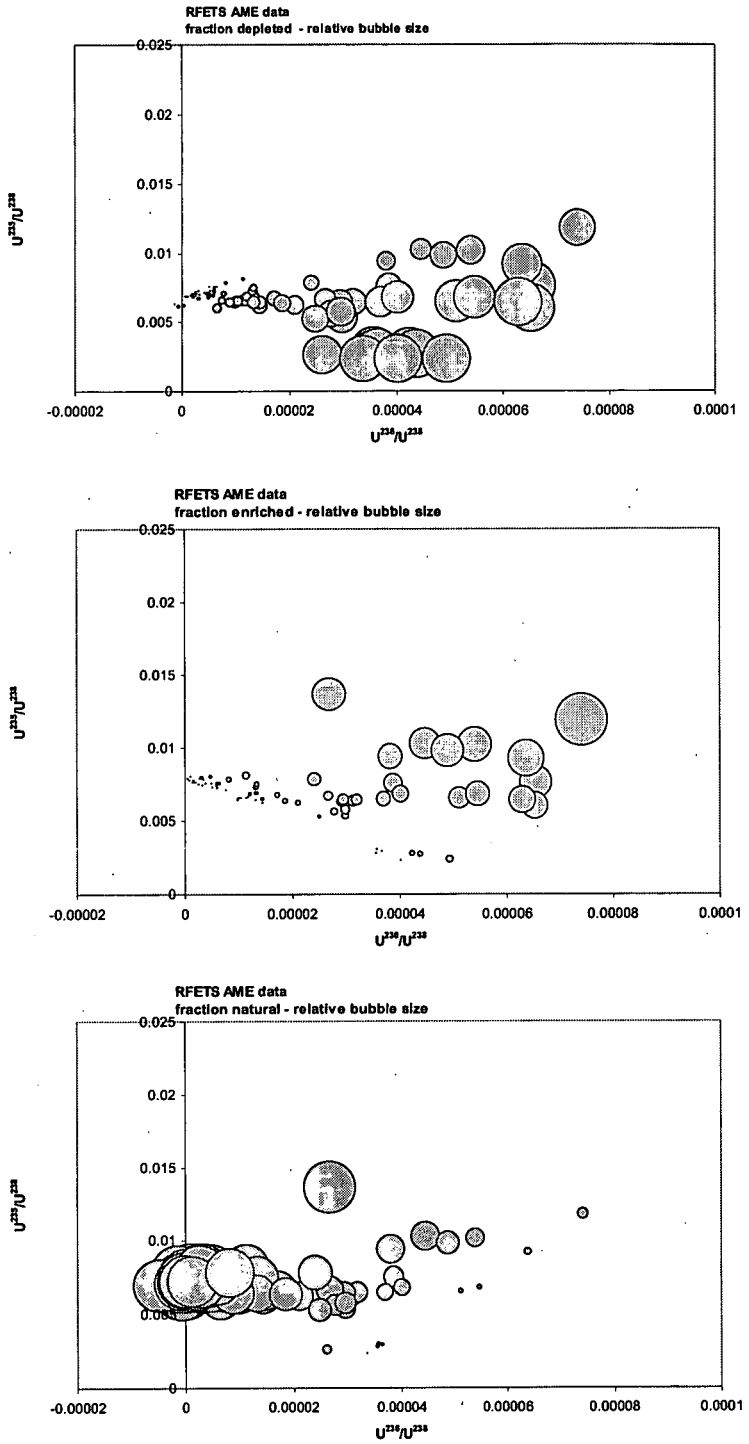

Figure 6. Qualitative evaluation of consistency in fraction evaluation results within the plot framework of Figure 2. Bubble size is proportional to the amount of each respective component calculated.

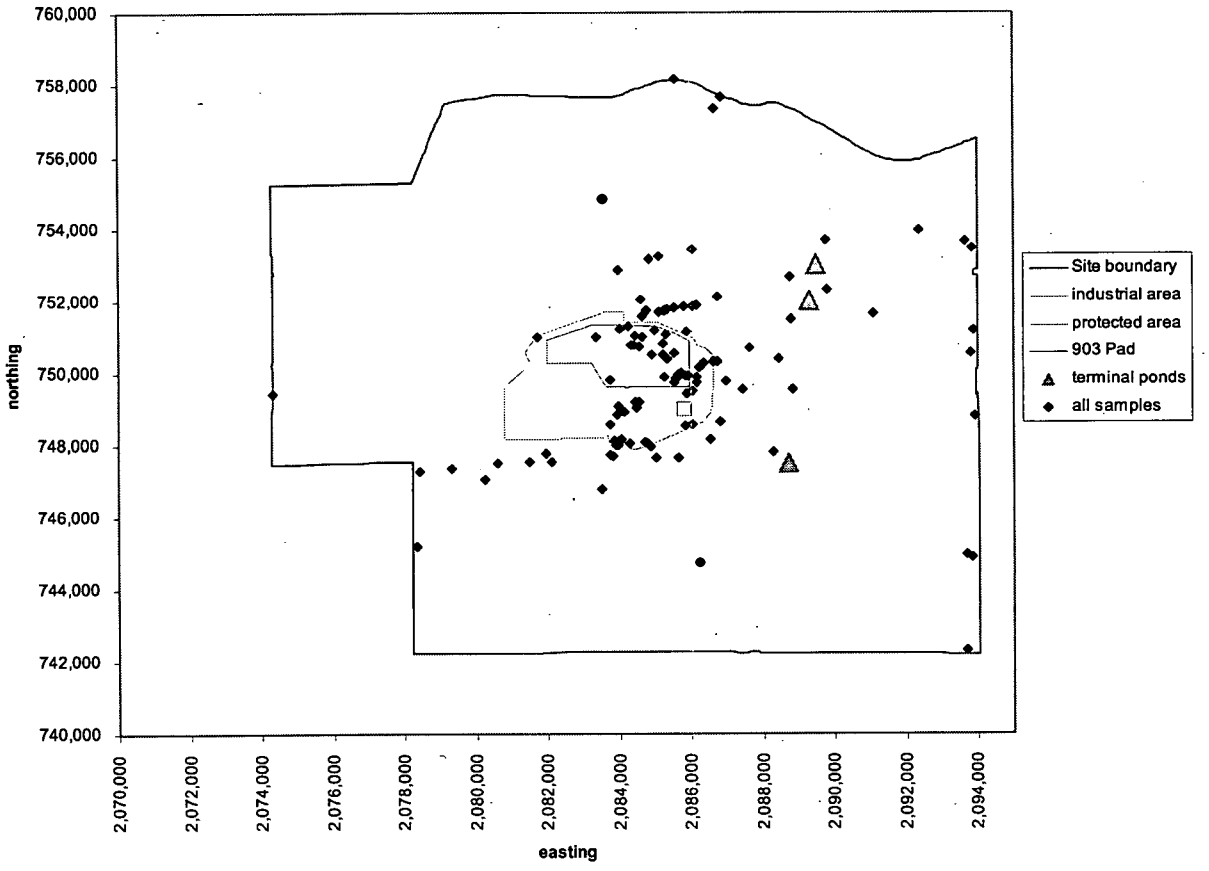

Figure 7a. Distribution of water samples analyzed for uranium isotopic composition by HR-ICP/MS or TIMS.

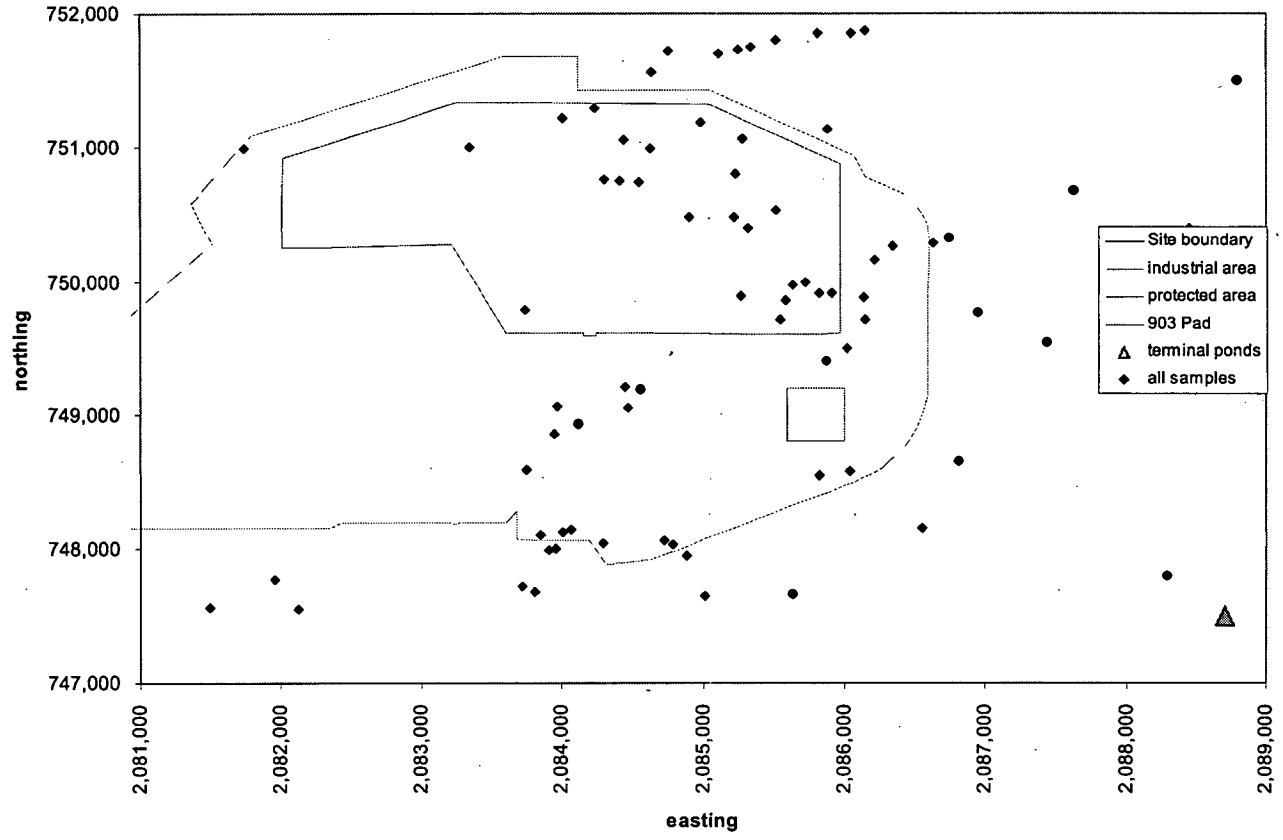

Figure 7b. Distribution of water samples analyzed for uranium isotopic composition by HR-ICP/MS or TIMS, focused on the Industrial Area.

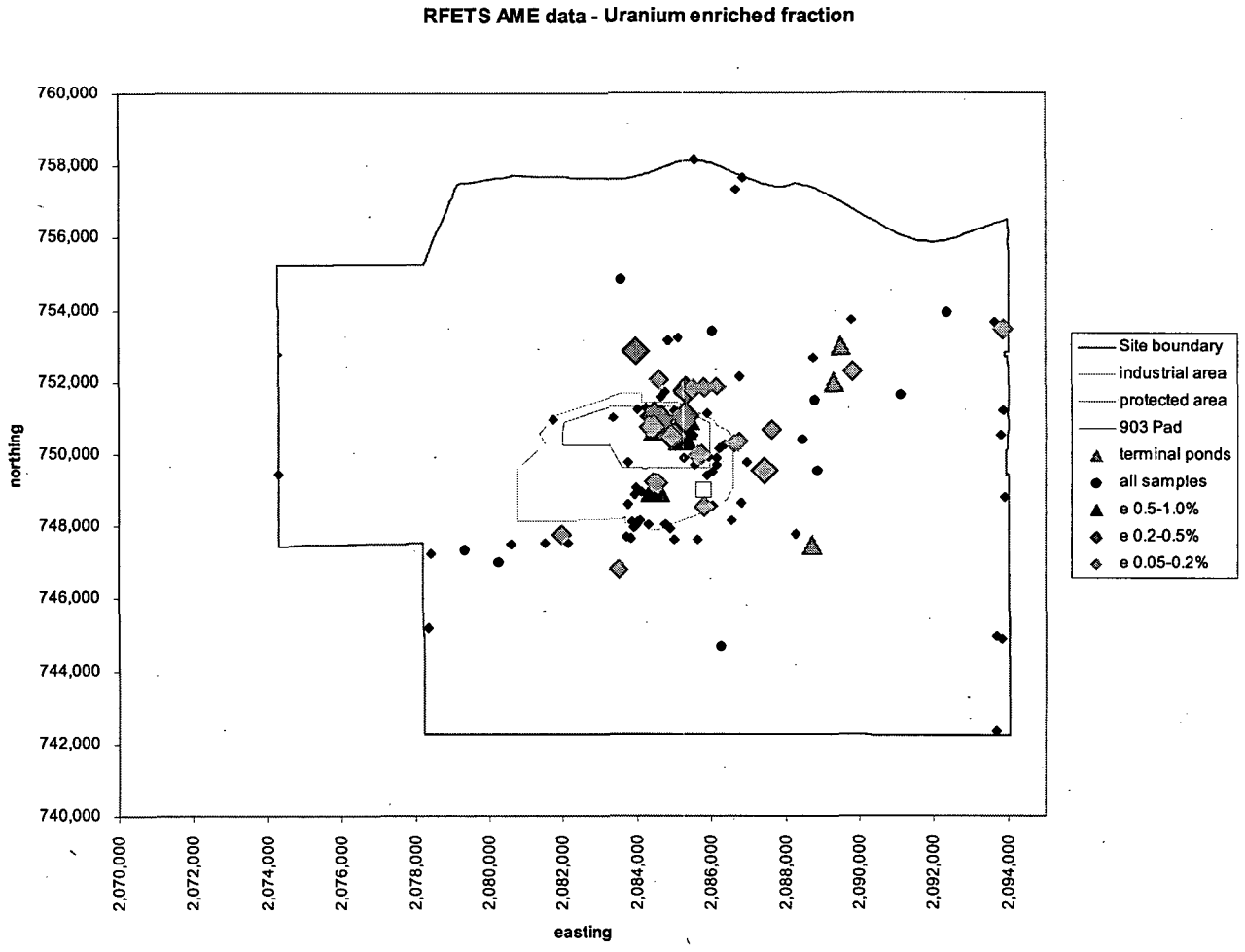

Figure 7c. Distribution of highly enriched uranium fraction geographically as a function of percent ranges.

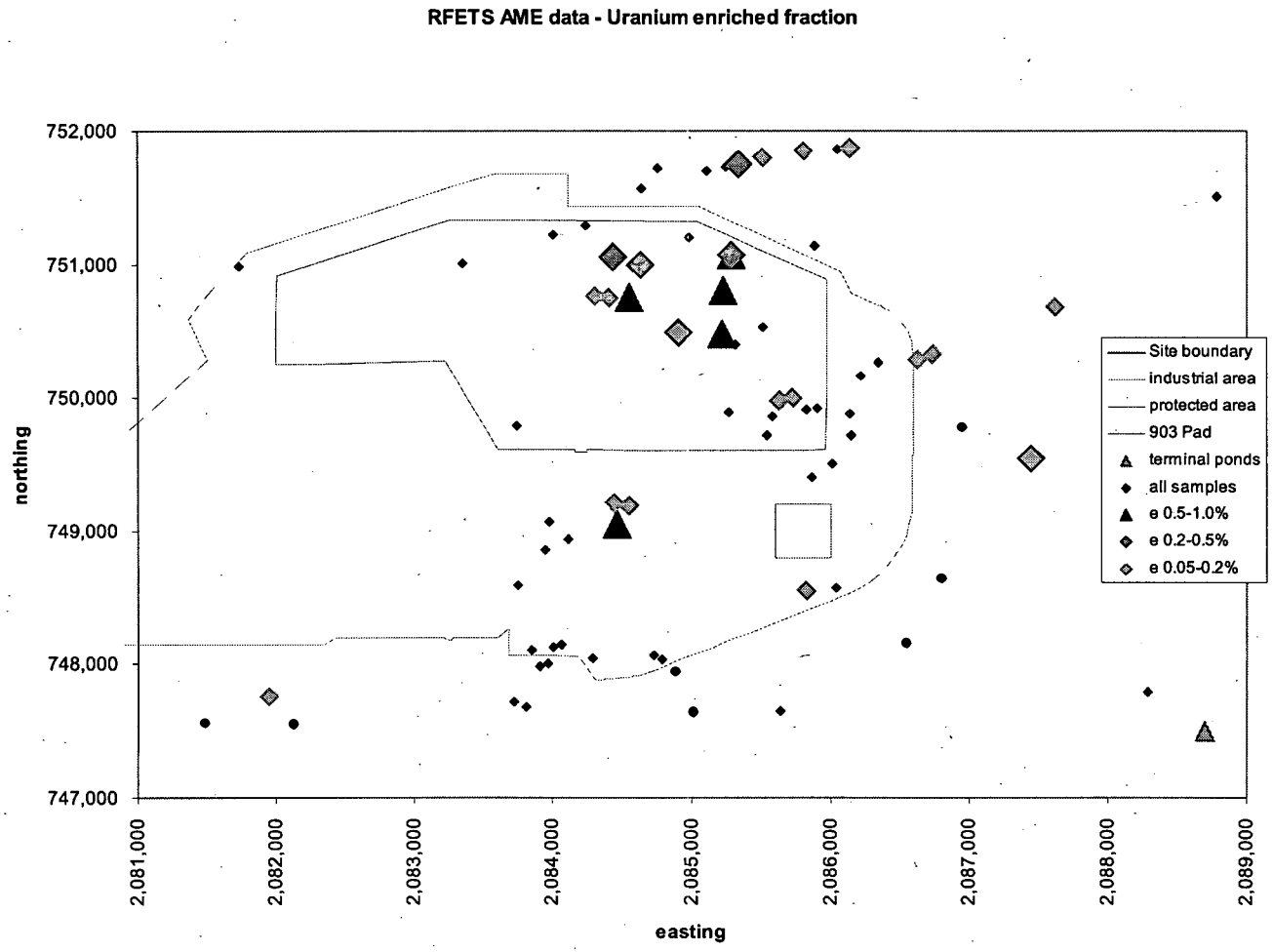

Figure 7d. Distribution of highly enriched uranium fraction geographically within the Industrial Area as a function of percent ranges.

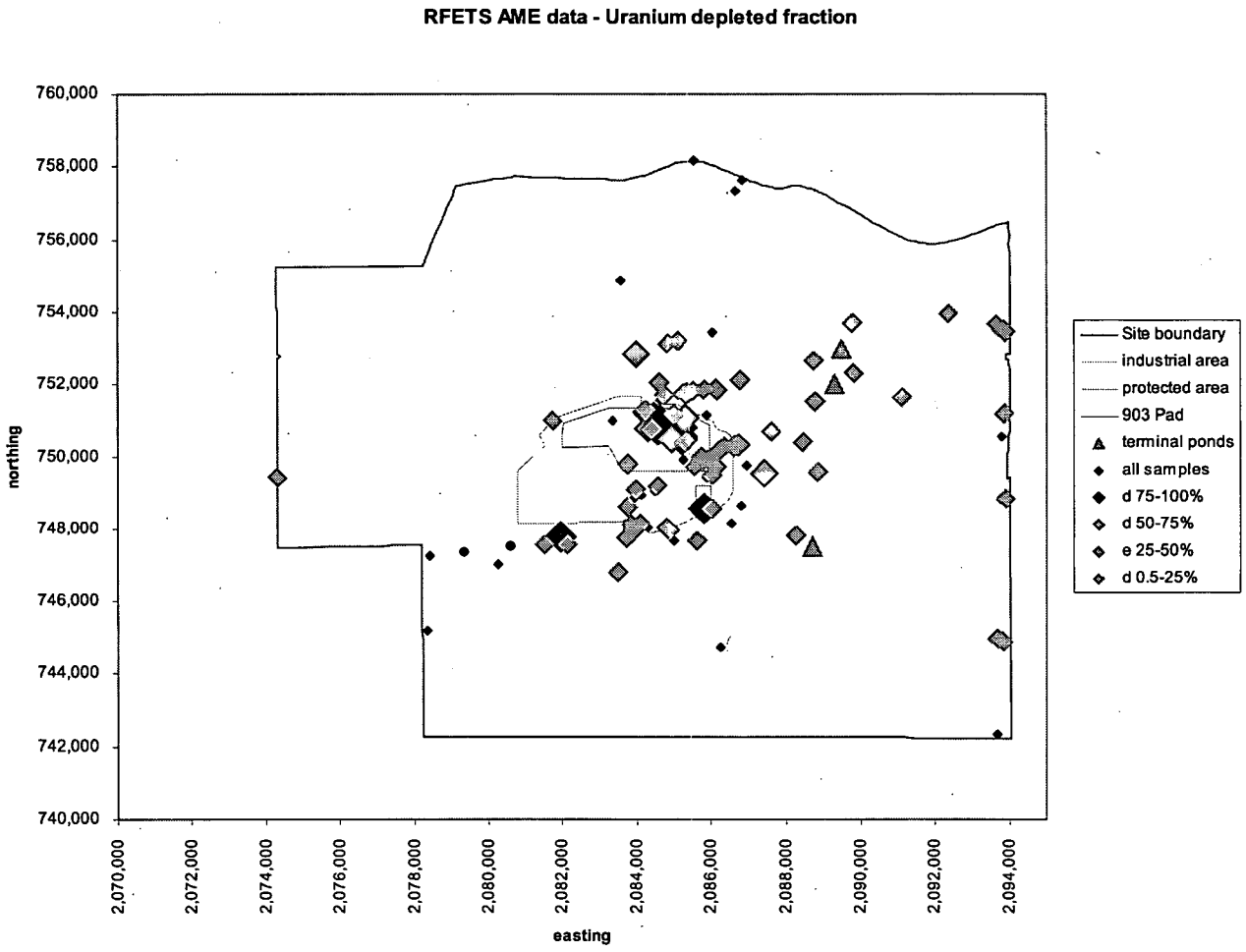

Figure 7e. Distribution of depleted uranium fraction geographically as a function of percent ranges.

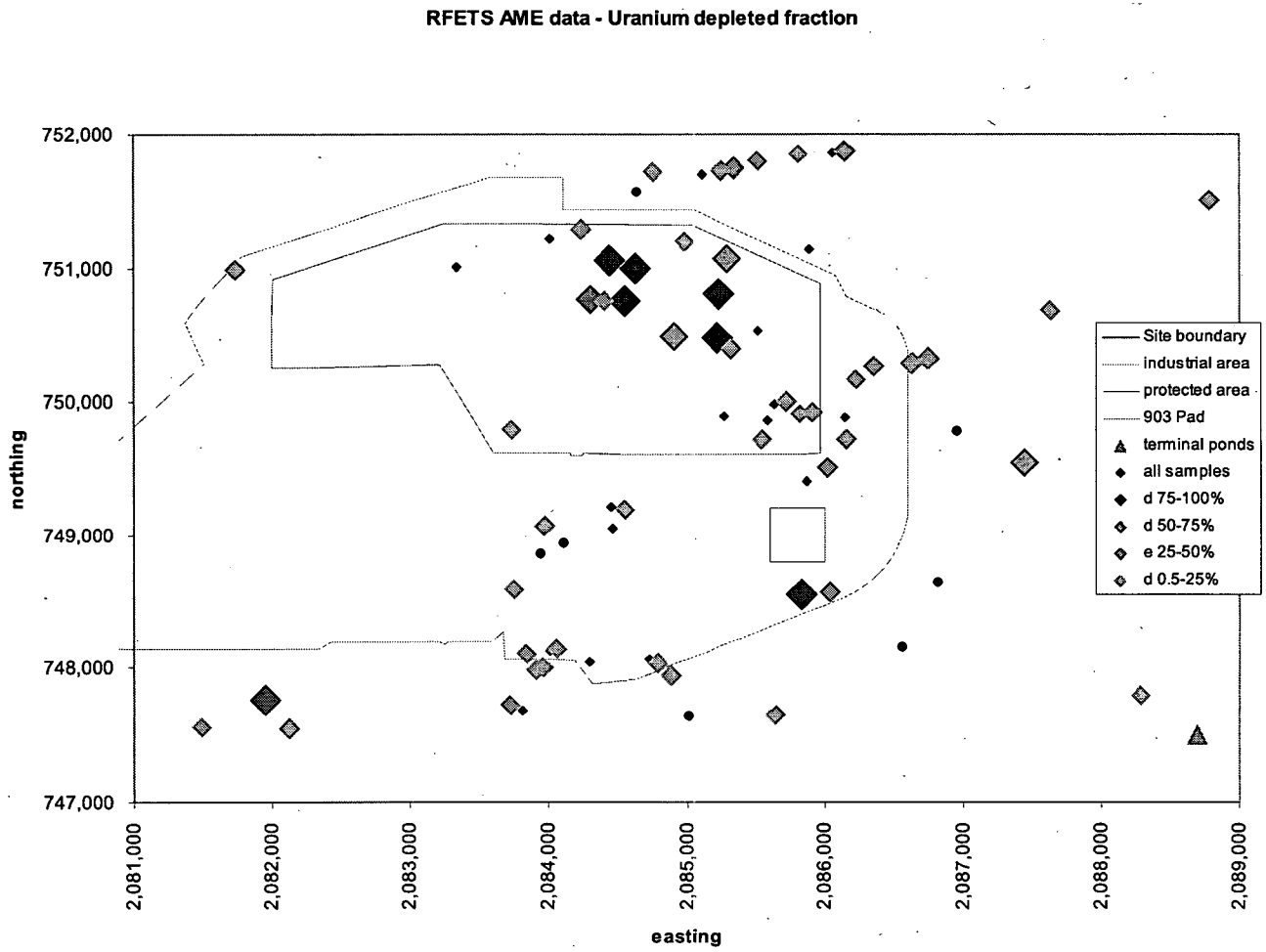

Figure 7f. Distribution of depleted uranium fraction geographically focused on the Industrial Area as a function of percent ranges.

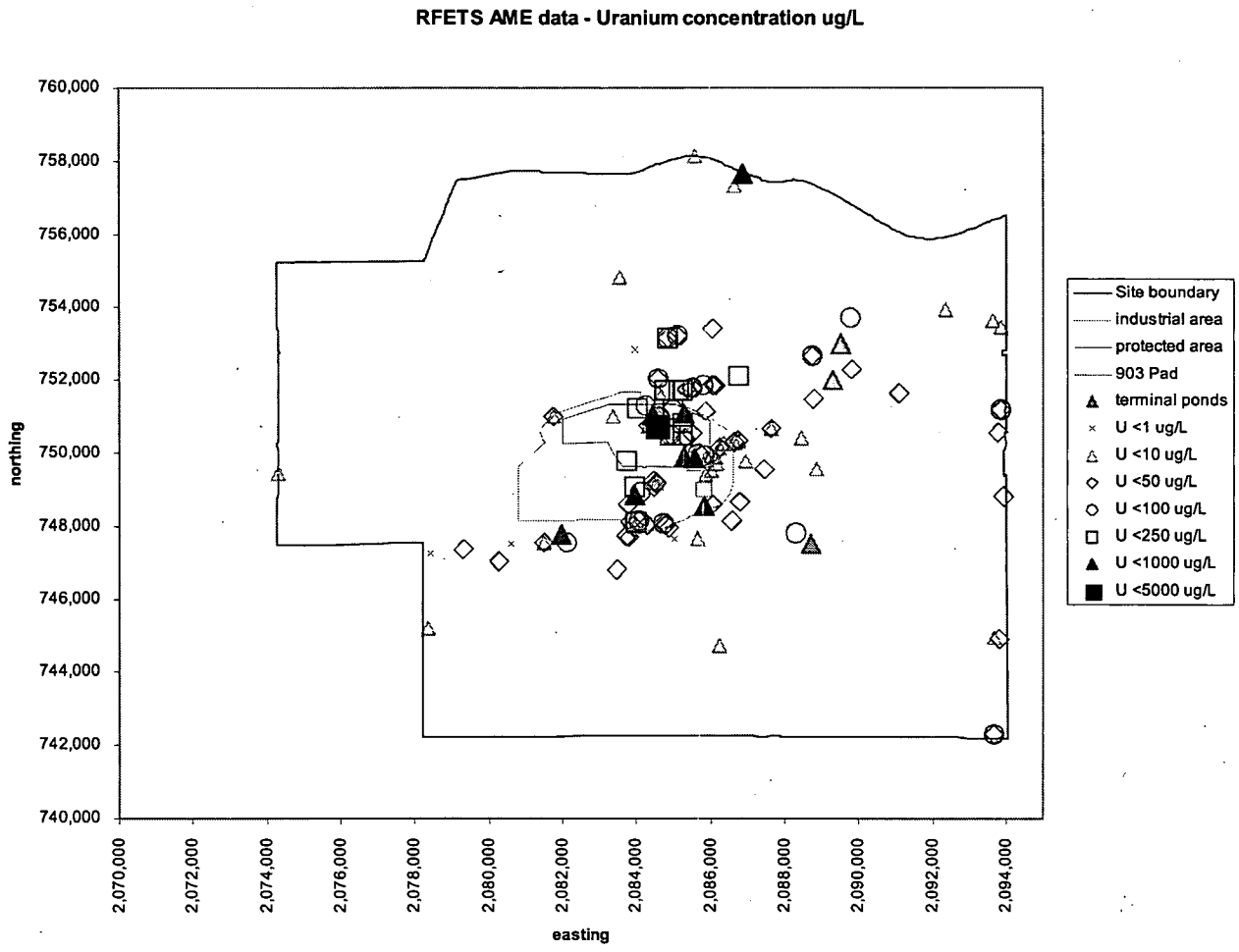

Figure 7g. Distribution of uranium concentrations geographically as a function of ug/L fractions.

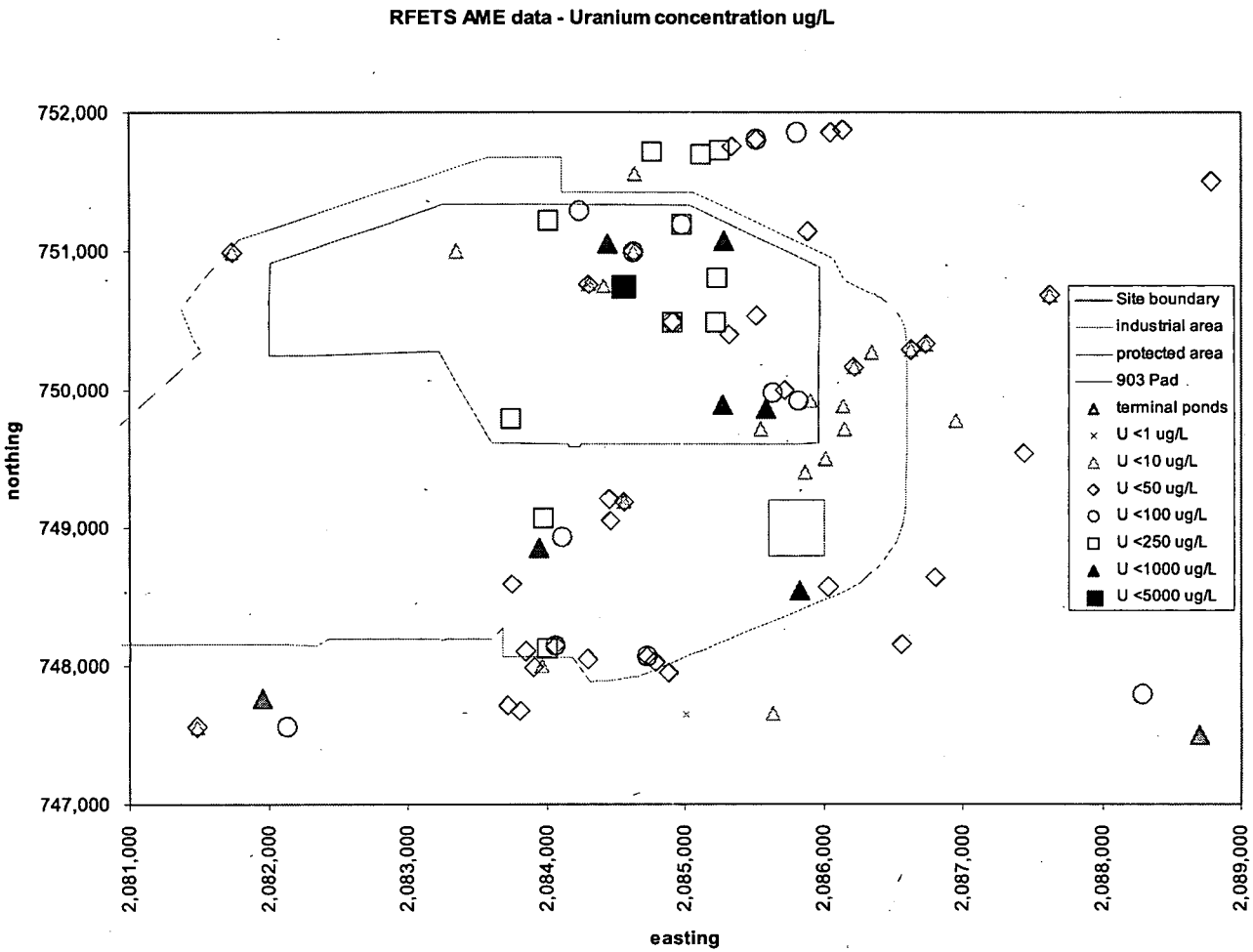

Figure 7h. Distribution of uranium concentrations geographically focused on the Industrial Area as a function of ug/L ranges.

Table 3. Summary of Uranium isotopic data and calculated % fractions of end-members (attached printout on following pages)

Samples with reported ^{236}U concentrations of below detection limits were assigned $^{236}U/^{238}U$ ratios of 1x10-11 and the cells highlighted in pink.

Table 3. Summary of Uranium isotopic data and calculated % fractions of end-members.

SUMMARY OF URANIUM DATA ANALYZED BY ICP/MS AND TIMS (Real data only - no QA data included)

normalize to % fractions (remove <0 & >100%)

Sample	Sample Locations	Easting	Northing	Sample Date	U ug/l	234/238	235/238	236/238	depleted	enriched	natural
16-10	00193	2088288.2	747793.9	6/24/1999	89.1	6.9160E-05	7.1877E-03	1.5710E-07	0.8%	0.00%	99.2%
18-75	00193	2088288.2	747793.9	12/1/1999	83.4	8.1820E-05	7.4649E-03	-2.0090E-07	0.0%	0.01%	100.0%
7-114	00193	2088288.2	747793.9	2/2/2000	80.0	7.8420E-05	7.0708E-03	-1.2330E-06	0.0%	0.00%	100.0%
14-180	00193	2088288.2	747793.9	6/12/2000	74.4	7.6920E-05	7.0580E-03	-8.3600E-07	0.3%	0.00%	99.7%
16-11	00491	2086806.9	748645.4	8/10/1999	11.8	8.2570E-05	7.3969E-03	-4.8500E-07	0.0%	0.00%	100.0%
18-76	00491	2086806.9	748645.4	12/6/1999	12.6	8.0690E-05	7.4857E-03	-5.2020E-07	0.0%	0.01%	100.0%
9-154	00491	2086806.9	748645.4	1/20/2000	12.4	7.9460E-05	7.3992E-03	-7.6960E-08	0.0%	0.01%	100.0%
14-181	00491	2086806.9	748645.4	4/21/2000	13.2	7.7480E-05	7.2977E-03	-1.4510E-06	0.0%	0.00%	100.0%
5-238	00897	2086154.0	749713.0	1/31/2001	7.0	8.7067E-05	7.0064E-03	1.8784E-06	4.9%	0.00%	95.1%
17-256	00897	2086154.0	749713.0	7/9/2002	7.1	9.2322E-05	7.2495E-03	1.7929E-06	2.8%	0.01%	97.2%
21-85	00997	2088788.0	751503.0	12/9/1999	16.0	7.4600E-05	6.2985E-03	-1.2220E-06	6.0%	0.00%	94.0%
9-155	00997	2088788.0	751503.0	1/20/2000	11.6	8.2230E-05	7.3783E-03	1.3230E-06	1.0%	0.02%	99.0%
14-182	00997	2088788.0	751503.0	4/18/2000	13.2	8.5640E-05	7.1644E-03	3.5090E-07	1.3%	0.00%	98.7%
5-228	00997	2088788.0	751503.0	7/28/2000	11.8	7.7341E-05	7.4893E-03	2.5393E-06	2.0%	0.03%	98.0%
17-250	01791	2086018.0	749504.0	6/24/2002	7.0	6.2819E-05	6.0311E-03	6.6094E-06	20.3%	0.00%	79.7%
17-257	02291	2086139.0	749879.9	7/3/2002	7.3	8.8130E-05	7.2690E-03	-2.6863E-07	0.0%	0.00%	100.0%
16-13	0386	2093777.9	750543.4	7/26/1999	24.0	7.0660E-05	7.4284E-03	-2.8810E-07	0.0%	0.01%	100.0%
18-73	0386	2093777.9	750543.4	10/14/1999	22.4	8.4830E-05	7.2683E-03	-1.8750E-06	0.0%	0.00%	100.0%
9-156	0386	2093777.9	750543.4	2/10/2000	22.0	7.3020E-05	7.0283E-03	-1.5650E-06	0.0%	0.00%	100.0%
14-183	0386	2093777.9	750543.4	4/20/2000	26.1	6.8790E-05	7.1302E-03	-2.2160E-06	0.0%	0.00%	100.0%
16-14	03991	2088449.2	750400.9	7/14/1999	3.4	8.3840E-05	6.9037E-03	1.0000E-11	2.9%	0.00%	97.1%
18-77	03991	2088449.2	750400.9	12/1/1999	3.5	7.2940E-05	6.9305E-03	1.6530E-06	5.2%	0.00%	94.8%
9-157	03991	2088449.2	750400.9	1/24/2000	3.4	8.8230E-05	6.8650E-03	-6.0000E-07	2.3%	0.00%	97.7%
14-184	03991	2088449.2	750400.9	4/17/2000	3.7	8.9980E-05	6.9433E-03	1.9420E-06	5.6%	0.00%	94.4%
13-158	0487	2084886.8	747943.1		33.3	7.5901E-05	7.3466E-03	2.5930E-06	3.2%	0.03%	96.7%
16-15	0487	2084886.8	747943.1	7/14/1999	33.6	6.6830E-05	6.8114E-03	2.0710E-06	6.9%	0.00%	93.1%
18-78	0487	2084886.8	747943.1	12/1/1999	30.9	7.5470E-05	7.4979E-03	7.4020E-07	0.0%	0.02%	100.0%
11-158	0487	2084886.8	747943.1	1/19/2000	34.1	8.2670E-05	7.2653E-03	1.0000E-11	0.0%	0.00%	100.0%
14-185	0487	2084886.8	747943.1	4/13/2000	31.7	7.5620E-05	7.2572E-03	-1.6320E-06	0.0%	0.00%	100.0%
16-2	04991	2088844.1	749551.1	6/17/1999	9.6	9.8520E-05	7.1308E-03	-7.5500E-07	0.0%	0.00%	100.0%
18-63	04991	2088844.1	749551.1	12/2/1999	9.8	8.8650E-05	6.8804E-03	-2.0870E-06	0.0%	0.00%	100.0%
7-115	04991	2088844.1	749551.1	2/1/2000	8.2	1.1460E-04	7.3167E-03	9.7680E-07	1.0%	0.01%	99.0%
14-225	05093	2085231.1	750804.2	4/3/2002	226.5	7.2688E-05	7.6463E-03	6.5481E-05	98.1%	0.55%	1.3%
14-224	05193	2085224.7	750483.6	4/8/2002	170.1	1.1800E-04	1.1860E-02	7.4114E-05	76.6%	0.85%	22.5%
15-237	0586	2089775.8	753703.3	6/19/2002	91.8	1.2227E-04	6.9006E-03	9.8012E-07	4.4%	0.00%	95.6%
16-17	06291	2091094.2	751639.0	6/24/1999	19.2	1.1940E-04	6.8502E-03	-1.0320E-06	1.7%	0.00%	98.3%
18-79	06291	2091094.2	751639.0	12/1/1999	19.2	1.2240E-04	7.1074E-03	-1.8650E-06	0.0%	0.00%	100.0%
7-116	06291	2091094.2	751639.0	2/22/2000	18.8	1.2940E-04	7.2252E-03	-3.8130E-07	0.0%	0.00%	100.0%
14-186	06291	2091094.2	751639.0	6/7/2000	18.7	1.2480E-04	7.0468E-03	-7.2670E-07	0.6%	0.00%	99.4%
16-18	06491	2093867.3	751192.9	7/15/1999	50.7	7.1240E-05	7.3136E-03	-2.0210E-07	0.0%	0.00%	100.0%
18-80	06491	2093867.3	751192.9	12/2/1999	47.5	8.9200E-05	7.9229E-03	5.8460E-07	0.0%	0.04%	100.0%
11-159	06491	2093867.3	751192.9	1/24/2000	50.7	8.6460E-05	7.1637E-03	-1.2930E-07	0.5%	0.00%	99.5%
15-187	06491	2093867.3	751192.9	4/20/2000	52.2	8.6660E-05	7.3263E-03	-7.9290E-07	0.0%	0.00%	100.0%
16-19	07391	2085827.2	748547.5	8/26/1999	268.6	1.7820E-05	3.0211E-03	3.5700E-05	90.3%	0.06%	9.7%
18-81	07391	2085827.2	748547.5	12/1/1999	282.6	1.8850E-05	2.7884E-03	3.5470E-05	91.8%	0.04%	8.1%
11-160	07391	2085827.2	748547.5	1/13/2000	297.2	1.4840E-05	2.8006E-03	4.2400E-05	100.0%	0.10%	-0.1%
15-188	07391	2085827.2	748547.5	6/19/2000	300.2	1.5410E-05	2.6144E-03	2.6190E-05	78.9%	0.00%	21.1%
5-246	07391	2085827.2	748547.5	3/6/2001	278.0	2.2527E-05	2.9132E-03	3.6445E-05	92.3%	0.06%	7.6%
16-20	07991	2087442.7	749541.1	6/28/1999	27.0	6.9090E-05	6.3483E-03	3.1210E-05	55.8%	0.20%	44.0%
18-82	07991	2087442.7	749541.1	12/1/1999	27.6	7.4360E-05	6.2976E-03	2.9080E-05	52.9%	0.18%	46.9%
7-117	07991	2087442.7	749541.1	2/3/2000	29.8	7.6600E-05	6.2163E-03	2.1110E-05	41.3%	0.11%	58.6%
15-189	07991	2087442.7	749541.1	6/19/2000	17.4	8.3890E-05	6.4506E-03	3.1930E-05	56.1%	0.21%	43.7%
17-251	09691	2086038.2	748571.9	6/18/2002	30.5	8.6189E-05	7.1409E-03	-1.5337E-07	0.7%	0.00%	99.3%
16-21	10294	2093691.2	742318.9	7/22/1999	53.6	6.1580E-05	7.3194E-03	-3.3370E-07	0.0%	0.00%	100.0%
11-161	10294	2093691.2	742318.9	1/19/2000	32.5	7.1620E-05	7.3066E-03	3.9650E-07	0.2%	0.01%	99.8%
16-22	10394	2093663.7	744946.9	8/30/1999	5.9	6.7410E-05	6.8999E-03	5.1100E-07	3.7%	0.00%	96.3%
21-86	10394	2093663.7	744946.9	11/4/1999	6.3	6.2940E-05	6.2123E-03	3.6860E-07	9.2%	0.00%	90.8%
11-162	10394	2093663.7	744946.9	2/11/2000	8.6	8.3400E-05	7.0076E-03	3.1780E-06	6.9%	0.01%	93.0%
15-190	10394	2093663.7	744946.9	4/21/2000	6.2	7.3670E-05	6.8292E-03	6.7160E-08	3.6%	0.00%	96.4%
16-247	10492	2083812.4	747677.9	6/20/2002	26.8	8.2865E-05	7.5049E-03	9.2615E-08	0.0%	0.01%	100.0%
16-3	10592	2083724.8	747715.8	6/17/1999	28.2	8.3330E-05	7.3639E-03	1.6370E-06	1.6%	0.02%	98.4%
18-66	10592	2083724.8	747715.8	11/2/1999	28.8	8.5980E-05	7.5793E-03	-9.8730E-07	0.0%	0.01%	100.0%
7-119	10592	2083724.8	747715.8	2/10/2000	31.7	7.6300E-05	7.0756E-03	-2.7440E-07	1.0%	0.00%	99.0%
14-175	10592	2083724.8	747715.8	5/22/2000	32.5	8.2490E-05	7.2078E-03	-6.1630E-07	0.0%	0.00%	100.0%
16-24	10594	2086746.5	752124.3	6/22/1999	108.1	7.8080E-05	7.0356E-03	5.4400E-08	1.9%	0.00%	98.1%
21-87	10594	2086746.5	752124.3	12/7/1999	128.0	8.3700E-05	7.2166E-03	1.0000E-11	0.3%	0.00%	99.7%
7-120	10594	2086746.5	752124.3	2/7/2000	132.5	8.8160E-05	7.1358E-03	-1.3200E-06	0.0%	0.00%	100.0%
15-191	10594	2086746.5	752124.3	6/8/2000	123.1	7.9870E-05	7.3248E-03	6.0600E-07	0.3%	0.01%	99.6%
21-88D	10694	2088757.1	752659.0		17.5	6.8030E-05	6.1841E-03	-5.2580E-07	8.0%	0.00%	92.0%
16-25	10694	2088757.1	752659.0	6/21/1999	19.9	6.8890E-05	6.7089E-03	3.1190E-06	9.3%	0.00%	90.7%
21-88	10694	2088757.1	752659.0	12/7/1999	16.4	6.6980E-05	6.8053E-03	8.1550E-09	3.7%	0.00%	96.3%
7-121	10694	2088757.1	752659.0	2/7/2000	18.6	8.6230E-05	7.0879E-03	-9.1160E-07	0.0%	0.00%	100.0%
15-192	10694	2088757.1	752659.0	6/8/2000	53.1	7.6600E-05	7.2739E-03	3.0260E-06	4.5%	0.03%	95.5%
5-242	10894	2092348.3	753948.2	1/31/2001	5.1	6.8914E-05	6.5983E-03	7.5721E-06	17.1%	0.03%	82.8%

Table 3. Summary of Uranium isotopic data and calculated % fractions of end-members.

16-26	11294	2074305.0	749435.2	6/23/1999	1.0	4.8900E-05	6.4633E-03	1.0000E-11	6.5%	0.00%	93.5%
7-122	11294	2074305.0	749435.2	2/15/2000	0.9	8.5760E-05	7.0048E-03	1.0000E-11	2.1%	0.00%	97.9%
17-252	12191	2086949.4	749774.2	6/24/2002	4.3	8.3558E-05	7.3424E-03	-7.5762E-08	0.0%	0.00%	100.0%
301	1386	2086051.2	751856.5	11/4/2004	18.0	7.2900E-05	7.2516E-03	3.0000E-08	0.1%	0.00%	99.9%
SEP	1586	2085811.7	751852.0		62.2	6.1000E-05	6.9200E-03	-1.7000E-06	0.1%	0.00%	99.9%
20-47	1586	2085811.7	751852.0	6/22/1999	70.7	7.4050E-05	7.5758E-03	6.1010E-06	6.8%	0.07%	93.2%
7-123	1586	2085811.7	751852.0	2/10/2000	63.5	6.3170E-05	7.0315E-03	5.0660E-06	9.7%	0.03%	90.3%
15-193	1586	2085811.7	751852.0	6/13/2000	55.4	6.7430E-05	6.9612E-03	5.7540E-06	11.3%	0.03%	88.6%
15-232	1586	2085811.7	751852.0	5/22/2002	57.3	6.4658E-05	6.8342E-03	2.2139E-06	6.9%	0.00%	93.1%
15-236	20098	2084239.0	751291.0	6/17/2002	92.4	7.6848E-05	7.0572E-03	-1.1478E-07	1.4%	0.00%	98.6%
20-27	22996	2084557.0	749188.0	8/11/1999	8.7	7.9800E-05	7.4338E-03	3.3770E-06	3.7%	0.04%	96.2%
18-72	22996	2084557.0	749188.0	11/3/1999	8.7	7.6590E-05	7.3675E-03	-1.7240E-07	0.0%	0.00%	100.0%
11-163	22996	2084557.0	749188.0	2/15/2000	0.5	4.2210E-05	7.0713E-03	7.7900E-06	13.6%	0.05%	86.4%
14-176	22996	2084557.0	749188.0	6/16/2000	10.5	8.4470E-05	7.2988E-03	1.9130E-08	0.0%	0.00%	100.0%
20-28	23296	2087624.0	750683.0	8/17/1999	29.4	8.5760E-05	8.1300E-03	1.1400E-05	10.4%	0.14%	89.5%
21-90	23296	2087624.0	750683.0	10/28/1999	33.7	8.3450E-05	7.5561E-03	3.8920E-06	3.5%	0.05%	96.4%
11-164	23296	2087624.0	750683.0	2/16/2000	2.7	7.6750E-05	6.7732E-03	4.8580E-06	11.5%	0.01%	88.5%
14-179	23296	2087624.0	750683.0	4/17/2000	40.1	7.4240E-05	7.1687E-03	4.0930E-06	7.0%	0.03%	92.9%
15-233	23296	2087624.0	750683.0	5/22/2002	42.2	7.1352E-05	7.2861E-03	6.0275E-06	9.1%	0.05%	90.9%
20-30	308-P-2	2084580.2	752051.8	6/24/1999	45.0	1.0010E-04	8.0323E-03	4.7750E-06	0.9%	0.08%	99.0%
18-84	308-P-2	2084580.2	752051.8	12/2/1999	55.4	8.7720E-05	6.8354E-03	-7.8750E-07	2.2%	0.00%	97.8%
7-125	308-P-2	2084580.2	752051.8	2/22/2000	53.6	8.2020E-05	7.2057E-03	-5.0930E-07	0.0%	0.00%	100.0%
15-194	308-P-2	2084580.2	752051.8	4/17/2000	55.2	7.7180E-05	7.2590E-03	1.1090E-06	1.7%	0.01%	98.3%
16-4	3586	2086219.1	750167.1	6/17/1999	11.1	7.7460E-05	6.9361E-03	5.4250E-07	3.5%	0.00%	96.5%
18-67	3586	2086219.1	750167.1	10/19/1999	9.0	6.7180E-05	6.9717E-03	1.9940E-06	5.4%	0.00%	94.6%
11-169	3586	2086219.1	750167.1	1/31/2000	8.7	7.6330E-05	7.2784E-03	-1.8320E-06	0.0%	0.00%	100.0%
18-221	3586	2086219.1	750167.1	5/18/2000	6.9	8.0570E-05	7.3911E-03	-1.3160E-06	0.0%	0.00%	100.0%
20-31	36391	2084294.0	748042.1	6/28/1999	26.0	7.0530E-05	6.9722E-03	-1.4880E-06	0.0%	0.00%	100.0%
21-91	36391	2084294.0	748042.1	12/1/1999	31.3	8.7100E-05	7.4438E-03	1.0000E-11	0.0%	0.01%	100.0%
7-126	36391	2084294.0	748042.1	2/3/2000	31.4	8.3760E-05	7.3020E-03	-1.6150E-07	0.0%	0.00%	100.0%
15-195	36391	2084294.0	748042.1	6/16/2000	30.0	7.8040E-05	7.2908E-03	3.6430E-07	0.3%	0.00%	99.7%
16-9	37791	2083753.4	748591.8	6/18/1999	26.3	6.4270E-05	7.4121E-03	3.7610E-07	0.0%	0.01%	100.0%
21-92	37791	2083753.4	748591.8	12/2/1999	28.9	6.2780E-05	7.1927E-03	-2.1080E-06	0.0%	0.00%	100.0%
7-127	37791	2083753.4	748591.8	2/8/2000	27.2	7.2940E-05	7.2101E-03	3.0200E-07	0.8%	0.00%	99.2%
15-196	37791	2083753.4	748591.8	6/12/2000	28.7	6.7590E-05	7.4597E-03	7.0090E-07	0.0%	0.02%	100.0%
21-93	37991	2084731.0	748063.1	12/1/1999	54.1	1.0000E-04	7.0964E-03	-1.2590E-06	0.0%	0.00%	100.0%
7-128	37991	2084731.0	748063.1	1/20/2000	48.1	9.5340E-05	7.5559E-03	-2.2240E-06	0.0%	0.00%	100.0%
15-197	37991	2084731.0	748063.1	6/19/2000	51.0	9.6770E-05	7.3376E-03	-7.8430E-07	0.0%	0.00%	100.0%
5-229	37991	2084731.0	748063.1	8/24/2000	47.2	7.4247E-05	7.1981E-03	-6.9864E-07	0.0%	0.00%	100.0%
16-1	4087	2084822.6	753142.6	6/17/1999	37.2	7.1280E-05	6.8860E-03	6.2290E-07	4.0%	0.00%	96.0%
11-170	4087	2084822.6	753142.6	1/14/2000	63.6	6.6750E-05	7.2238E-03	2.5310E-06	4.2%	0.02%	95.8%
14-177	4087	2084822.6	753142.6	4/20/2000	54.1	7.5480E-05	7.1505E-03	2.4110E-07	1.2%	0.00%	98.8%
16-241	41099	2084451.6	749207.8	6/18/2002	36.9	8.3820E-05	8.0117E-03	1.1612E-06	0.0%	0.05%	99.9%
5-236	41199	2084467.7	749052.1	2/1/2001	11.5	1.2996E-04	1.3657E-02	2.6883E-05	0.0%	0.56%	99.4%
20-34	41591	2093914.0	748799.8	8/12/1999	20.8	6.8720E-05	7.2673E-03	9.8780E-08	0.0%	0.00%	100.0%
18-74	41591	2093914.0	748799.8	10/19/1999	19.5	4.9070E-05	7.1320E-03	4.2630E-07	1.7%	0.00%	98.3%
11-165	41591	2093914.0	748799.8	2/16/2000	25.5	6.2490E-05	7.3346E-03	1.0000E-11	0.0%	0.00%	100.0%
15-198	41591	2093914.0	748799.8	4/20/2000	27.7	7.6060E-05	7.5400E-03	-1.8710E-07	0.0%	0.01%	100.0%
20-35	41691	2093851.2	753470.3	7/27/1999	5.0	5.6300E-05	6.1898E-03	1.4470E-05	31.2%	0.06%	68.7%
21-94	41691	2093851.2	753470.3	12/7/1999	2.5	8.0620E-05	6.4025E-03	9.9330E-06	22.4%	0.03%	77.6%
11-166	41691	2093851.2	753470.3	1/5/2000	2.6	7.2890E-05	6.4630E-03	1.4530E-05	29.0%	0.07%	70.9%
15-199	41691	2093851.2	753470.3	4/24/2000	2.9	5.9630E-05	6.5751E-03	1.0150E-05	21.3%	0.05%	78.6%
15-235	41691	2093851.2	753470.3	5/28/2002	2.6	6.4591E-05	6.5679E-03	1.1386E-05	23.3%	0.05%	76.7%
SEP	42993	2084552.4	750748.0		2987.7	8.3300E-05	9.2300E-03	6.3700E-05	82.3%	0.62%	17.1%
17-253	4386	2085868.9	749404.1	6/20/2002	2.4	7.0949E-05	7.2022E-03	-1.0072E-06	0.0%	0.00%	100.0%
17-254	4387	2084787.9	748029.5	6/25/2002	19.3	6.9239E-05	7.1743E-03	1.4476E-06	2.9%	0.01%	97.1%
SEP	43993	2084908.9	750486.4		100.4	5.9400E-05	6.4100E-03	2.9400E-05	52.5%	0.19%	47.3%
18-55	43993	2084908.9	750486.4	6/28/1999	43.8	7.0750E-05	7.5796E-03	3.8650E-05	57.1%	0.33%	42.5%
8-129	43993	2084908.9	750486.4	2/28/2000	47.3	6.9900E-05	6.6718E-03	2.6740E-05	46.2%	0.18%	53.6%
15-200	43993	2084908.9	750486.4	5/9/2000	50.4	6.2890E-05	6.4674E-03	3.6950E-05	63.7%	0.26%	36.0%
16-246	5187	2083850.3	748102.8	6/28/2002	13.2	7.9778E-05	7.2568E-03	1.5315E-06	2.3%	0.01%	97.6%
5-237	5287	2084066.7	748145.1	1/31/2001	36.8	6.8304E-05	7.4113E-03	1.7144E-06	1.3%	0.02%	98.6%
14-223	5287	2084066.7	748145.1	6/10/2002	57.9	7.8174E-05	7.7946E-03	9.5775E-07	0.0%	0.04%	100.0%
16-5	52894	2085098.9	753221.6	6/17/1999	41.7	6.8450E-05	6.8021E-03	-6.1160E-07	2.8%	0.00%	97.2%
18-69	52894	2085098.9	753221.6	8/26/1999	38.9	7.7460E-05	7.6687E-03	-7.8580E-07	0.0%	0.02%	100.0%
14-178	52894	2085098.9	753221.6	5/22/2000	60.5	7.1810E-05	6.9831E-03	-6.7290E-07	1.2%	0.00%	98.8%
20-37	53194	2086036.6	753434.3	6/28/1999	29.0	2.4430E-05	7.6411E-03	1.5540E-06	0.0%	0.03%	100.0%
8-130	53194	2086036.6	753434.3	2/7/2000	29.5	8.1540E-05	7.3936E-03	8.2790E-07	0.1%	0.01%	99.9%
16-201	53194	2086036.6	753434.3	6/13/2000	30.2	7.5560E-05	7.3379E-03	-5.9480E-07	0.0%	0.00%	100.0%
16-7	5387	2083912.0	747985.0	6/17/1999	18.3	8.0660E-05	7.6252E-03	2.0430E-06	0.1%	0.04%	99.9%
18-65	5387	2083912.0	747985.0	12/1/1999	18.4	6.8200E-05	7.7558E-03	-1.8330E-07	0.0%	0.03%	100.0%
8-131	5387	2083912.0	747985.0	2/10/2000	17.5	7.6300E-05	7.7705E-03	1.7140E-06	0.0%	0.04%	100.0%
14-174	5387	2083912.0	747985.0	6/22/2000	20.6	7.1340E-05	7.4715E-03	1.5400E-06	0.6%	0.02%	99.4%
304	58793	2080605.3	747511.5	2/15/2005	0.3	7.4100E-05	7.3314E-03	5.0000E-09	0.0%	0.00%	100.0%
16-249	59093	2079327.0	747350.2	6/20/2002	33.7	8.8258E-05	7.3334E-03	-1.1589E-06	0.0%	0.00%	100.0%
20-38	59393	2081489.1	747555.2	6/22/1999	11.3	5.7990E-05	7.3407E-03	1.0450E-06	0.9%	0.01%	99.1%
21-96	59393	2081489.1	747555.2	12/7/1999	16.0	7.6730E-05	7.1262E-03	-7.1720E-07	0.0%	0.00%	100.0%
8-132	59393	2081489.1	747555.2	2/8/2000	7.8	7.5230E-05	7.2492E-03	8.8650E-07	1.4%	0.01%	98.6%
16-202	59393	2081489.1	747555.2	6/12/2000	15.5	6.9430E-05	7.3508E-03	9.6530E-07	0.7%	0.01%	99.3%

Table 3. Summary of Uranium isotopic data and calculated % fractions of end-members.

13-133	59793	2082128.1	747552.6		75.8	6.5970E-05	7.2294E-03	-1.1210E-06	0.0%	0.00%	100.0%
21-97	59793	2082128.1	747552.6	12/2/1999	73.1	7.9290E-05	7.3581E-03	7.1560E-08	0.0%	0.01%	100.0%
8-133	59793	2082128.1	747552.6	2/10/2000	75.2	6.2190E-05	7.0567E-03	1.0000E-11	1.6%	0.00%	98.4%
16-203	59793	2082128.1	747552.6	6/12/2000	68.5	6.1530E-05	7.2663E-03	-5.4230E-07	0.0%	0.00%	100.0%
16-248	59793	2082128.1	747552.6	6/20/2002	57.3	7.0443E-05	7.1308E-03	-8.4988E-07	0.0%	0.00%	100.0%
15-240	60699	2083741.2	749790.1	6/18/2002	121.9	7.6544E-05	7.2783E-03	1.3131E-06	1.8%	0.01%	98.2%
20-40	61093	2081952.0	747764.3	6/28/1999	346.7	9.2360E-05	2.7260E-03	4.3760E-05	100.0%	0.11%	-0.1%
21-98	61093	2081952.0	747764.3	12/7/1999	766.5	1.4280E-05	2.3333E-03	4.9380E-05	100.0%	0.13%	-0.1%
8-134	61093	2081952.0	747764.3	2/17/2000	769.5	1.0950E-05	2.3305E-03	3.3630E-05	92.8%	0.00%	7.2%
16-204	61093	2081952.0	747764.3	5/3/2000	523.5	9.4860E-06	2.3199E-03	4.0220E-05	100.0%	0.06%	-0.1%
15-238	70099	2084761.0	751716.0	6/19/2002	222.0	7.7929E-05	7.2682E-03	4.4644E-07	0.6%	0.00%	99.4%
305	71394	2080265.5	747027.0	2/15/2005	11.8	8.1200E-05	7.2939E-03	1.0000E-11	0.0%	0.00%	100.0%
20-41	75292	2089809.0	752305.0	6/24/1999	29.3	7.8190E-05	7.4290E-03	5.9280E-06	7.7%	0.06%	92.2%
22-99	75292	2089809.0	752305.0	12/2/1999	33.1	7.7310E-05	7.5740E-03	5.0520E-06	5.2%	0.06%	94.8%
8-138	75292	2089809.0	752305.0	2/9/2000	22.3	8.6790E-05	7.3262E-03	5.2000E-06	7.4%	0.05%	92.5%
16-208	75292	2089809.0	752305.0	6/12/2000	37.4	8.4620E-05	7.2244E-03	1.7320E-06	2.9%	0.01%	97.1%
20-42	75992	2086628.0	750290.0	7/27/1999	31.0	7.4960E-05	6.8596E-03	1.3240E-05	23.7%	0.09%	76.2%
22-100	75992	2086628.0	750290.0	12/2/1999	21.9	5.9610E-05	6.6034E-03	1.1670E-05	23.4%	0.06%	76.5%
11-167	75992	2086628.0	750290.0	1/24/2000	20.1	7.1970E-05	6.8831E-03	1.3290E-05	23.6%	0.09%	76.3%
16-209	75992	2086628.0	750290.0	6/12/2000	22.8	6.7480E-05	6.8539E-03	1.2150E-05	22.1%	0.08%	77.8%
14-222	75992	2086628.0	750290.0	6/10/2002	8.9	7.9531E-05	6.7401E-03	1.7245E-05	30.9%	0.11%	69.0%
300	79102	2084441.4	751052.8	6/22/2004	801.0	5.7900E-05	6.4475E-03	6.4200E-05	100.0%	0.47%	-0.5%
16-243	83201	2083947.1	748857.2	6/18/2002	403.0	7.1485E-05	7.2054E-03	6.6298E-08	0.5%	0.00%	99.5%
17-259	86501	2083972.1	749066.9	7/10/2002	122.8	7.3418E-05	7.2698E-03	7.4316E-07	1.0%	0.01%	99.0%
17-258	86701	2084115.2	748933.6	7/10/2002	91.1	6.6595E-05	7.2681E-03	9.1827E-09	0.0%	0.00%	100.0%
16-242	88101	2084009.0	748122.6	6/18/2002	148.1	8.7496E-05	7.2912E-03	7.1425E-08	0.0%	0.00%	100.0%
5-244	90099	2086556.6	748154.1	3/8/2001	10.2	7.3289E-05	7.3231E-03	1.1519E-07	0.0%	0.00%	100.0%
298	99101	2085272.8	749895.3	6/29/2004	397.0	7.7000E-05	7.2516E-03	1.0000E-11	0.0%	0.00%	100.0%
?	99305	2085632.9	5939.5	6/27/2005		7.8100E-05	8.0026E-03	3.2000E-06	0.0%	0.07%	99.9%
17-255	99401	2085586.3	749861.8	7/10/2002	652.7	7.7947E-05	7.3758E-03	-2.4484E-07	0.0%	0.00%	100.0%
SEP	B201589	2086648.3	757328.4		2.1	6.0900E-05	7.3300E-03	-1.8800E-07	0.0%	0.00%	100.0%
SEP	B203189	2083556.5	754848.2		3.9	9.6300E-05	7.9100E-03	-1.4600E-06	0.0%	0.02%	100.0%
SEP	B205589	2086855.2	757654.1		294.1	7.0400E-05	7.1500E-03	-1.4000E-06	0.0%	0.00%	100.0%
20-43	B205589	2086855.2	757654.1	6/24/1999	286.0	1.7410E-05	7.5774E-03	1.3830E-06	0.0%	0.03%	100.0%
8-139	B205589	2086855.2	757654.1	2/9/2000	287.1	8.4550E-05	7.3888E-03	-2.2650E-07	0.0%	0.01%	100.0%
5-232	B206989	2084835.2	753145.2	12/13/2000	104.5	9.0332E-05	7.3673E-03	-4.5091E-07	0.0%	0.00%	100.0%
14-229	B208189	2085885.1	751138.0		27.1	9.1002E-05	7.5186E-03	6.3615E-07	0.0%	0.02%	100.0%
14-229D	B208189	2085885.1	751138.0	3/20/2002	27.4	7.5320E-05	7.2706E-03	-8.4350E-07	0.0%	0.00%	100.0%
SEP	B208689	2085249.9	751727.9		150.9	7.4600E-05	7.1700E-03	-1.2800E-06	0.0%	0.00%	100.0%
20-46	B208689	2085249.9	751727.9	6/21/1999	146.5	9.7580E-05	7.6026E-03	7.0330E-07	0.0%	0.02%	100.0%
9-143	B208689	2085249.9	751727.9	2/10/2000	144.1	8.7950E-05	7.3402E-03	-1.3290E-06	0.0%	0.00%	100.0%
16-210	B208689	2085249.9	751727.9	4/18/2000	133.6	9.6510E-05	7.3313E-03	1.0630E-06	1.0%	0.01%	99.0%
14-230	B210389	2085116.4	751695.8	3/20/2002	142.7	8.9406E-05	7.1364E-03	-4.0072E-07	0.3%	0.00%	99.7%
SEP	B210489	2085513.2	751801.9		55.1	6.6500E-05	7.2200E-03	3.9900E-07	0.9%	0.00%	99.1%
20-48	B210489	2085513.2	751801.9	6/22/1999	73.4	8.0940E-05	7.5854E-03	6.2590E-06	6.9%	0.07%	93.0%
9-147	B210489	2085513.2	751801.9	1/31/2000	54.8	7.0240E-05	7.3041E-03	1.3240E-05	20.1%	0.11%	79.8%
18-214	B210489	2085513.2	751801.9	4/18/2000	46.1	7.7010E-05	7.4979E-03	1.3370E-05	18.7%	0.12%	81.2%
20-44	B302089	2083490.5	746786.3	6/28/1999	42.8	8.9420E-05	7.8417E-03	3.4910E-06	0.5%	0.06%	99.4%
9-148	B302089	2083490.5	746786.3	2/14/2000	44.5	8.5640E-05	7.0774E-03	-1.8940E-06	0.0%	0.00%	100.0%
SEP	B305389	2086232.0	744718.0		8.7	6.6100E-05	7.2900E-03	2.4700E-07	0.1%	0.00%	99.9%
SEP	B405489	2078357.0	745190.8		2.4	1.2800E-04	7.1700E-03	-7.2400E-07	0.0%	0.00%	100.0%
514-001	GS01	2093819.9	744894.4	5/1/2002	10.3	7.1052E-05	7.0822E-03	2.0622E-06	4.6%	0.01%	95.4%
514-002	GS03	2093622.1	753639.9	5/1/2002	2.3	6.1873E-05	6.5107E-03	9.9071E-06	21.5%	0.04%	78.5%
514-003	GS04	2085567.9	758144.8	5/1/2002	1.8	6.7613E-05	7.2059E-03	-1.1662E-08	0.4%	0.00%	99.6%
514-004	GS05	2078428.0	747260.2	5/1/2002	0.2	6.0758E-05	6.9733E-03	-4.6507E-06	0.0%	0.00%	100.0%
514-005	GS10	2086741.0	750326.0	5/1/2002	9.6	6.0976E-05	6.5283E-03	1.0415E-05	22.1%	0.04%	77.8%
514-006	GS13	2086144.8	751871.7	5/1/2002	16.0	6.1095E-05	6.4138E-03	1.3277E-05	27.5%	0.06%	72.4%
514-007	GS17	2085638.2	747649.6	5/1/2002	2.7	7.1119E-05	7.1398E-03	1.2547E-06	2.9%	0.00%	97.1%
20-45	P114389	2081738.8	750990.4	7/21/1999	6.4	7.6690E-05	7.0545E-03	4.8160E-06	9.1%	0.03%	90.9%
22-105	P114389	2081738.8	750990.4	12/8/1999	10.1	7.1300E-05	7.0892E-03	-8.4900E-07	0.0%	0.00%	100.0%
11-168	P114389	2081738.8	750990.4	1/26/2000	6.2	8.4880E-05	7.1727E-03	-3.2030E-07	0.2%	0.00%	99.8%
18-215	P114389	2081738.8	750990.4	4/18/2000	8.8	8.5560E-05	7.2236E-03	6.1830E-07	1.2%	0.00%	98.8%
22-106	P207689	2085318.0	750398.0	12/2/1999	31.6	6.8970E-05	7.4053E-03	1.8590E-06	1.6%	0.02%	98.4%
9-149	P207689	2085318.0	750398.0	2/1/2000	29.6	7.6270E-05	7.3178E-03	-3.9860E-07	0.0%	0.00%	100.0%
18-216	P207689	2085318.0	750398.0	5/4/2000	31.8	7.9090E-05	7.1412E-03	1.8820E-06	3.8%	0.01%	96.2%
SEP	P209189	2084309.0	750762.0		13.2	3.9500E-05	5.3300E-03	2.9800E-05	62.0%	0.14%	37.8%
22-107	P209189	2084309.0	750762.0	12/15/1999	8.8	4.7650E-05	5.5832E-03	2.7860E-05	56.9%	0.13%	42.9%
9-150	P209189	2084309.0	750762.0	2/1/2000	0.5	4.0210E-05	5.2600E-03	2.4970E-05	55.1%	0.09%	44.8%
18-217	P209189	2084309.0	750762.0	5/4/2000	9.9	4.6230E-05	5.7373E-03	2.9700E-05	58.5%	0.16%	41.3%
SEP	P209489	2084634.0	750991.0		43.4	5.9100E-05	6.5300E-03	5.1200E-05	85.2%	0.37%	14.4%
16-8	P209489	2084634.0	750991.0	6/23/1999	45.5	5.7980E-05	6.7987E-03	5.4670E-05	88.4%	0.42%	11.2%
9-151	P209489	2084634.0	750991.0	1/31/2000	9.9	6.8200E-05	5.9941E-03	6.5310E-05	100.0%	0.46%	-0.5%
18-220	P209489	2084634.0	750991.0	5/4/2000	56.2	6.0730E-05	6.4262E-03	6.3040E-05	100.0%	0.46%	-0.5%
SEP	P209589	2085286.0	751071.0		414.1	1.0300E-04	1.0300E-02	4.4700E-05	44.0%	0.53%	55.5%
22-108	P209589	2085286.0	751071.0	12/6/1999	475.9	1.0130E-04	1.0191E-02	5.3990E-05	59.3%	0.59%	40.1%
9-152	P209589	2085286.0	751071.0	2/28/2000	320.4	1.1200E-04	9.8251E-03	4.8900E-05	54.4%	0.53%	45.0%
18-218	P209589	2085286.0	751071.0	5/9/2000	321.8	7.2970E-05	9.4194E-03	3.8160E-05	41.2%	0.43%	58.4%
14-228	P209689	2085514.0	750533.0	3/25/2002	47.5	7.9728E-05	7.6218E-03	1.1923E-07	0.0%	0.02%	100.0%
SEP	P209889	2084984.0	751194.0		102.3	7.8500E-05	7.3200E-03	1.1600E-06	1.2%	0.01%	98.7%

Table 3. Summary of Uranium isotopic data and calculated % fractions of end-members.

22-109	P209889	2084984.0	751194.0	12/20/1999	90.0	7.8660E-05	7.2241E-03	2.1330E-06	3.5%	0.02%	96.4%
9-153	P209889	2084984.0	751194.0	2/1/2000	91.2	7.6130E-05	7.0919E-03	2.1350E-06	4.6%	0.01%	95.4%
18-219	P209889	2084984.0	751194.0	5/9/2000	96.1	8.4110E-05	7.3643E-03	2.4850E-07	0.0%	0.01%	100.0%
303	P210089	2084639.3	751563.5	11/9/2004	9.0	8.7100E-05	7.2674E-03	7.0000E-09	0.0%	0.00%	100.0%
15-231	P210189	2084410.8	750752.2	3/26/2002	3.6	8.2604E-05	7.5554E-03	6.5292E-06	7.6%	0.07%	92.3%
299	P219189	2084010.0	751222.0	6/23/2004	117.0	7.5500E-05	7.2622E-03	1.0000E-11	0.0%	0.00%	100.0%
15-239	SPP DIS GALLERY	2085339.4	751751.4	6/18/2002	40.5	7.7564E-05	7.8281E-03	2.4123E-05	32.6%	0.23%	67.2%
514-009	STP	2086347.0	750267.0		9.9	6.4486E-05	6.4305E-03	8.8854E-06	20.6%	0.03%	79.4%
5-243A	SW097	2083957.0	752846.6	1/31/2001	0.3	7.0628E-05	6.7934E-03	4.0221E-05	66.1%	0.30%	33.6%
5-243B	SW13494	2083963.7	748000.2		8.4	6.6626E-05	7.2401E-03	6.0990E-06	9.5%	0.05%	90.4%
514-008	SW18	2083350.6	751006.4	5/1/2002	5.2	8.0665E-05	7.4064E-03	-1.1208E-07	0.0%	0.01%	100.0%
									-	-	-
									-	-	-
99305	99305	2085632.9	749978.0	8/8/2005	53.7	7.8100E-05	8.0026E-03	3.2000E-06	0.0%	0.07%	99.9%
99305	99305	2085632.9	749978.0	8/8/2005	54.5	7.7600E-05	7.9051E-03	2.8000E-06	0.0%	0.06%	99.9%
99405	99405	2085584.8	749862.7	8/8/2005	395.7	7.4800E-05	7.2464E-03	1.0000E-11	0.1%	0.00%	99.9%
91203	91203	2085909.8	749919.0	8/8/2005	3.9	7.6200E-05	6.9444E-03	2.6000E-06	6.6%	0.00%	93.4%
91305	91305	2085822.7	749915.2	8/9/2005	54.1	7.6100E-05	7.0972E-03	2.8000E-06	5.6%	0.01%	94.4%
89104	89104	2085012.6	747640.6	8/18/2005					-	-	-
GS10	GS10	2086741.0	750326.0	8/11/2005	13.2	5.7500E-05	6.3613E-03	1.8600E-05	36.2%	0.10%	63.7%
SW056	SW056	2085544.3	749713.2	8/2/2005	9.5	7.6400E-05	7.2098E-03	1.3000E-06	2.4%	0.01%	97.6%
SW141	SW141	2085725.0	749997.0	8/2/2005	16.3	7.6600E-05	7.8493E-03	8.3000E-06	7.9%	0.10%	92.0%